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TOPOGRAPHICAL FEATURES AND THE CLIMATE OF BRITAIN: A REVIEW OF SOME OUTSTANDING EFFECTS

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GREAT BRITAIN is relatively small, and for centuries it has been recognized by those descriptive writers who can be claimed as the ancestors of to-day's regional geographers, that we enjoy a temperate climate. Yet it was early appreciated that there are decided differences in the prevailing quality or "feel" of the air from place to place, and notably that the results of increased exposure to wind are immediately evident. (For example, Speed, 1611, on Lancashire, "the air is subtile and piercing.") The stranger coming to England equipped with the older generalizations is often surprised at these very effective differences of climate. A well-known Swiss geologist confronted for the first time, after ten minutes climb in a car, with a wide stretch of the northern Pennines, declared to me that "this was the tundra"; and inquired how this could be at an altitude of only 520 metres, about that of Berne. One can find in Great Britain small-scale examples of almost every meteorological phenomenon.

It is proposed in this paper to call attention to the available material, to show how it can be used, and to claim the geographer's prerogative: the preliminary assemblage and interpretation of a variety of phenomena on a quantitative basis, which have not yet been extensively reviewed. To these data others will undoubtedly apply more detailed analysis; and add further material from neglected districts. Geographers hitherto have tended to neglect the resolution of existing climatological observations.

The climate of this island is remarkably "marginal" in the sense that very slight changes of altitude, aspect, and soil have considerable effects. One may judge that during post-glacial and even historic times variations have occurred both in temperature and in effective rainfall, and have had very marked effects on the habitability of many districts. It follows that no country is more capable of advantageous modification by individual effort, and now that we must make the best use of "all the qualities o' the isle," those who plan land

utilization may well require material not commonly available to assess, generally or locally, the possibilities of our present-day climate.

Even within the period covered by instrumental records the climatic vicissitudes have left their impression, notably as regards winter; our perceptions and opinions are particularly affected by the visible results of changes of temperature about freezing-point. On a normal winter day with continuous precipitation, rain only will be observed while the surface temperature of the air is above 39°; at 38° a motorist will note an occasional flake of melting snow on his windscreen; at 35° melting snowflakes will predominate; but at 32° dry snow will be drifting before the wind. Hence a relatively small change in the mean temperature of a winter month, whether due to altitude or otherwise, is likely to have conspicuous results. Again, spring as a whole is subject to rather severe frosts [1] and variations in their incidence and intensity are of great importance to the gardener. Variations in average temperature from place to place are perhaps less marked in summer, but they become conspicuous when the average day-time maxima are taken into account; here altitude combined with exposure to wind again becomes very effective. Variations in evaporation, sunshine, and rainfall are also noteworthy and may be critical with regard to the yield of crops; further, over much of the south-east, variations in the winter rainfall markedly affect the percolation. This relationship between rainfall and percolation has recently been discussed by W. V. Lewis (*Proc. Geol. Ass.* 84 (1943) 171); there is considerable evidence that the earlier eighteenth century was as a whole drier than at present over the whole of the south-east, and we have no reason to believe that such conditions will not return. This would very seriously affect the water supply of the whole of south-east England, and might well afford another somewhat unexpected demonstration of the significance of small changes in the climate of this marginal island.

The vicissitudes of our climate in time have been discussed in many papers, notably by Dr. C. E. P. Brooks.[2] A number of long temperature and rainfall records have been conveniently summarized in recent years, for example, those kept at Oxford, Durham, and Kew.[3]

In this paper I consider some of the more subtle variations in place at the present day. The material can be gathered from the Meteorological Office *Monthly Weather Report* (published from 1884), provided that it is used with close attention to the environment of the three hundred odd available stations and to the hours of observations.

For in Britain daily maxima and minima are not always so important as the extremes, especially in milder places. Further, the rate of change and frequency of simultaneous change of several climatic elements between one part of the country and another may be more significant than the change in any one element. For example, compare the proportion of "sunny hours" to

[1] A. S. Watt, "Climate of Cambridgeshire" (from 'The Cambridge region,' ed. H. Darby, 1938).

[2] C. E. P. Brooks, "The climate of the first half of the 18th century," *Q.J.R. Met. Soc.* 56 (1930) 389.

[3] Oxford: 1932, *Radcliffe Observations* (1926–30) 55, Appendix. Durham: 1941, G. Manley, *Q.J.R. Met. Soc.* 67 (1941) 67, 363. Kew: 1943, A. J. Drummond, *Q.J.R. Met. Soc.* 69 (1943) 147.

"hours with measurable rainfall during the daytime," on the Sussex coast with that in the wetter parts of the mountainous Western Highlands; the ratio is about eight times as large in Sussex, and such results, integrated in the visitor's mind, make a more lasting impression than the difference in average cloud amount or quantity of rain measured.

Climatic differences are perhaps susceptible of interpretation with the aid of concepts from other fields of study. It may be suggested that the human frame responds in a considerable degree not to the prevalent wind, but, like the trees and the coastline itself, to the dominant wind. The prevalent wind is south-westerly in Sussex and Northumberland, at Aberystwyth and Aberdeen; but the dominant impression on the minds of those dwelling on our eastward and northward coasts is often imposed by the north-easter. Differences of aspect too are effective; the landscape offers a very different impression where the majority of slopes are inclined away from the sun.[1] Near London many will recall the contrast between the exposed north-eastern flank of the Chilterns near Dunstable and the more favoured sheltered slopes towards Berkhampstead. It remains for others to give better quantitative expression to these results of observation, as none of the official stations are so placed as to afford adequate data. I should say that a station on an exposed north-easterly slope will commonly give shade maxima in summer averaging 2°–3° below those at the same level in a more sheltered position; on many sunny days the difference would be likely to exceed 5°. Bilham [2] has described some of the normal modifications at coastal stations, while Tylor (*Q.J.R. Met. Soc.* 61 (1935)), Bonacina, and others have called attention to the very marked differences in regard to "bracing" and "relaxing" qualities. There is room for more work here; not the least of our island advantages is that small but significant changes in local climate are easily made; compare, for example, the Cambridge townsman's regard for Newmarket. It would appear that much depends on the frequency with which small local exchanges of air differing slightly in quality are effected by land and sea breezes or by surface turbulence, a large lapse rate, and appreciable momentary variations in temperature and humidity.

Variations in precipitation

Variations in rainfall in relation to the physical features of Britain have long been studied and mapped. A further problem however deserving examination is the relation between the profitable reclamation of land in the past and the rainfall, run-off, and evaporation. The limits determining the present extent of enclosed and improved pastures lie in most cases close to the 65-inch isohyet on Dartmoor, 55 in Central Wales, tending to decrease on the Pennines, in Galloway, and Arran, and falling to about 40 inches in Caithness. In wetter districts improvement is practically confined to the valley floors. Accordingly, the altitudinal limit of settlement must remain very low in our wetter mountain districts; it only approaches the treeline in one place, namely the northern Pennines, where the highest habitation (1980 feet) in the British Isles is found near the head of Teesdale.

[1] Minnaert, 'Light and colour in the open air' (*c.* 1939).
[2] Bilham, 'The climate of the British Isles,' 1938.

Variations in snowfall, snow-cover, and the incidence of frost are also related to physical features, but have not received so much attention. Hence I shall particularly consider these three elements bearing in mind their relation to land utilization to show the use of existing climatological records.

Snowfall and snow-cover

In a temperate climate such as ours, where the winter means at sea-level range from 39° to 45°, the frequency of snowfall increases rapidly with a slight fall in temperature. The number of days on which snow or sleet is generally observed to fall averages only four or thereabouts in South Cornwall; but it rises with latitude and proximity to colder air supplies to upwards of twenty in the Outer Hebrides and to nearly forty in Shetland. In the London district and south-east Midlands, apart from the built-up London area, the frequency at low levels is of the order of fifteen days, diminishing to about ten in Inner London.

The accompanying map, based on one originally published and discussed in the *Meteorological Magazine* for April 1940 (Manley, G., p. 45), has been drawn for stations below 200 feet; at higher levels up to about 1500 feet the average number of days with snow shows everywhere a very consistent increase with altitude, one day for every 50 feet.[1] Hence in the North Pennines snow or sleet can be expected to fall on upwards of fifty days yearly; similar figures apply on Upper Deeside and Speyside in the Highlands, and are approached, for example, in the upland valleys of Peeblesshire. Indeed the very rapid increase in the frequency of snow, and, as we shall see, of snow-cover, just south of Edinburgh is one of the most striking climatic features of Scotland; the meteorological reasons for this have been cited in the above-named article.

Snow-cover is an element whose observation and mapping is difficult in our country. The *Monthly Weather Report* gives the number of days on which "more than half the country surrounding the station, at the same level and typical of the station itself, is covered with snow at the morning observation (9h.)." Hence this "number of mornings with snow lying" is not likely to approximate to the "number of days duration" except when the mean temperature falls close to the freezing-point; but it is certainly probable that the two figures approach each other in all the upland regions of Britain during the colder months. By estimation, the correspondence is reasonably close whenever the mean temperature for the whole month is below 38°. Moreover the statistics as given cannot take account of "days with persistent snowdrifts in sheltered places"; and as, at high levels on our mountains, the greater part of the snowfall is accompanied by drifting, many drifts remain long after the period when an observer would describe the country as "less than half covered" at a particular level.

In an earlier paper (*Q.J.R. Met. Soc.* 65 (1939) 2) I showed that the frequency of snow-cover in any part of Britain bears a relationship to the mean temperature, the aspect, and the quantity as well as the frequency with which

[1] This paper is mainly concerned with incidence of frost at low levels; the results observed at high levels have been made available in papers in the *Q.J.R. Met. Soc.* (G. Manley, 1936, 1942, and 1943).

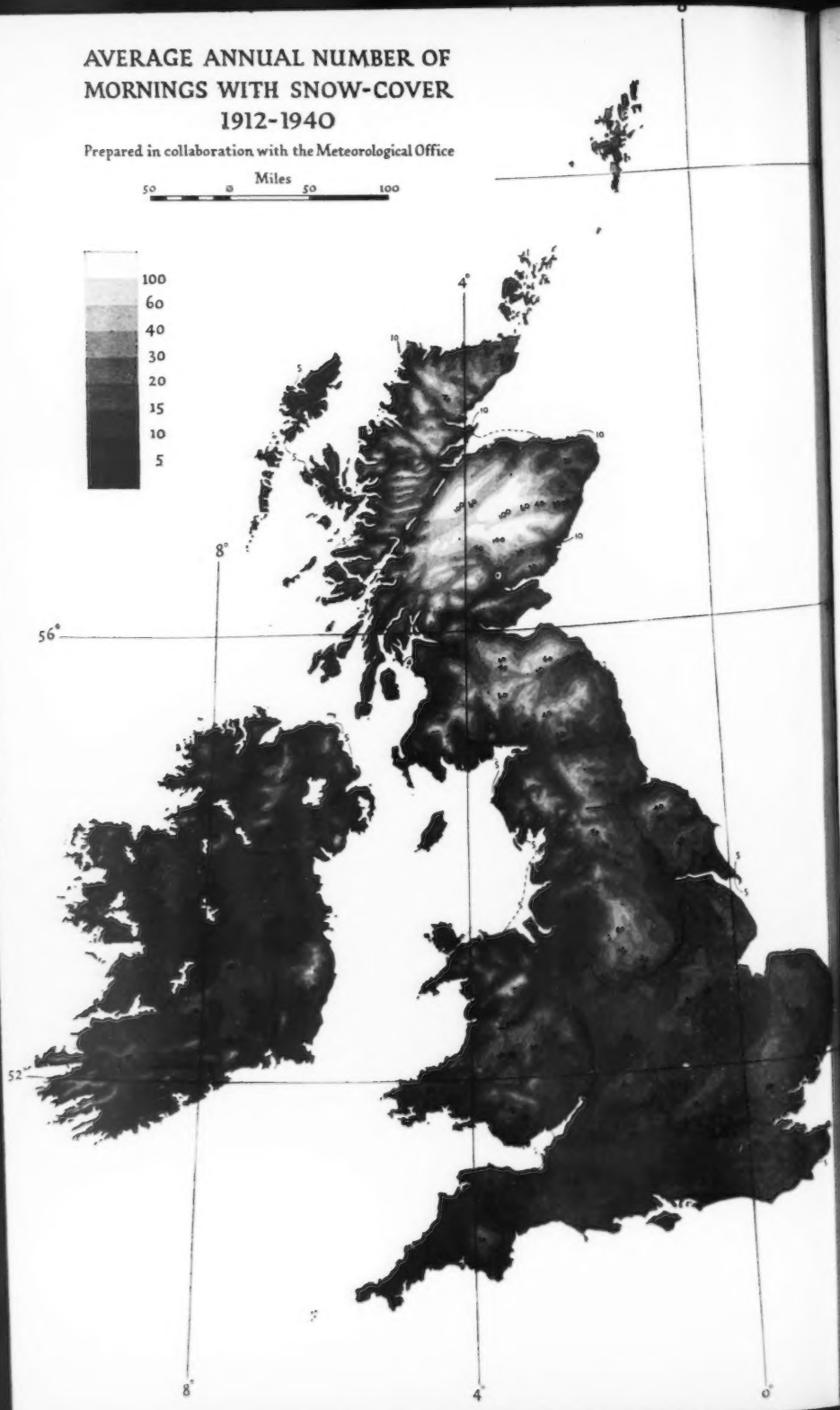
AVERAGE ANNUAL NUMBER OF DAYS WITH SNOW ON LOW GROUND 1912-1938

To correct for altitude add 1 day for every 50 ft. above 200 ft.

Redrawn from the map published in the Meteorological Magazine April 1940 No. 891 Vol. 75 (H.M.S.O. London).

AVERAGE ANNUAL NUMBER OF MORNINGS WITH SNOW-COVER 1912-1940

Prepared in collaboration with the Meteorological Office



the snow falls. In general the quantity increases for orographic reasons on all our eastward-facing uplands. Accordingly snow-cover becomes a very prominant feature of the winter climate throughout, for example, the uplands of Aberdeenshire, the Lammermuirs, and Durham; and dwellers in the high-lying suburbs of the West Riding industrial towns are probably more conscious of urban snowfalls than anywhere else in Britain.

I have attempted to show the main features of the distribution of snow-cover in the accompanying map, based primarily on material prepared for the above-mentioned paper, but it also incorporates some observations made since that time and not yet officially published. At the same time, the drawing of the map probably reveals features which have become known to me as the result of official association with the Meteorological Office, who are shortly publishing charts embodying more detailed information. On this map altitude is allowed for throughout, as far as the scale permits; all the details for highland districts cannot be shown. Comment may however be directed to some outstanding features. In London, the urban effect halves the average annual number of mornings with snow-cover from about five in the outer suburbs to less than three in Kensington; but altitude causes an increase to about thirteen at the summit of Hampstead Heath (450 feet). Probably an average exceeding twenty will be found at Whipsnade (700 feet) on the Chilterns, which is certainly higher than the average for Princetown (1430 feet) on Dartmoor, and approaches the figure for Harrogate (478 feet).

At 1000 feet on the east of the Pennines the average annual expectation varies between thirty and forty; the increase with altitude thereabouts is very rapid, rising from about seven on the Durham coast to about eighty days in extreme Upper Teesdale (1840 feet) on the limits of cultivation (Manley, *Q.J.R. Met. Soc.* 69 (1943) 251). In Aberdeenshire there is a similar increase from about thirteen at Aberdeen to sixty-nine at Braemar on Deeside (1120 feet). Farther north the frequency of snowfall on exposed islands is considerable, but that of snow-cover is relatively slight (Lerwick, thirty-eight and ten respectively). Ireland is relatively free from snow-cover, south of the Ulster border; while in the far south-west, in both Ireland and Cornwall, the chance of a morning with snow-cover adjacent to the coast diminishes to a figure of the order of one in two years. In the Fenland, for a number of reasons, snow-cover is appreciably less frequent at Cambridge than in Norfolk generally.

The range of the variation in the annual number of days with snow-cover is important. The experience of the last thirty years suggests that over most of South Britain and wherever the annual normal is less than ten the range is from zero in a mild year to about four times the normal in a severe year, *e.g.* with an average of 13 Hampstead has varied from 1 to 61. Farther north the range at inland stations is from two or three mornings in a mild year to three times the normal or thereabouts (Durham, average 18, range 3–67). At high levels the range is from under half to double the normal, *e.g.* Balmoral, average 61, range 27–116; West Linton, average 40, range 13–88.

Snow-cover on upland roads hinders transport, and some figures have already been given (*Geogr. J.* 92 (1938) 34). Preliminary observations made for the Association for Study of Snow and Ice, show that at high levels large snowdrifts are likely to remain conspicuous for from one-third to one-half as

long again as prevailing snow-cover. Badly sited upland roads owe their disadvantages far more to remediable defects of construction than to any meteorological cause.

The average expectation of snow-cover bears a close relationship to mean temperature up to about 1500 feet. Above this it is difficult to decide what constitutes snow-cover on our windswept uplands. On the higher summits, above 2000 feet, the frequency of snow-cover is rather less than might be estimated from the temperature alone; on Dun Fell (2735 feet) about one hundred days with snow-cover can be expected yearly, whereas temperature alone would suggest about one hundred and forty days.

In more continental climates, a hundred mornings with snow-cover can be regarded as approximately continuous cover from mid-December to mid-March, and this is desirable for effective winter sports. No inhabited part of Britain satisfactorily fulfils these requirements partly on account of drifting and exposure of summits. The nearest approach to persistent snow-cover with reasonable shelter is probably in the great upland valleys of the Cairngorms at 2000 feet.

A very small decrease in average temperature will have marked effects in all our upland districts. There is little doubt that, had statistics of snow-cover been kept during the period 1870–97, the averages at high-lying villages in the north-east, would have exceeded those on which the present map is based by as much as 50 per cent.

Relief and the incidence of frost

In undulating country the ponding of the cold air on clear nights in hollows and valleys is familiar. E. L. Hawke has pointed out (*Q.J.R. Met. Soc.* 59 (1933) 261) that relatively few people in this country live in the bottoms of valleys; hence climatological stations are rarely in a position to record the lowest temperatures on those nights, common at all seasons, when inversion occurs in a surface layer a few hundred feet thick. After such ponding of the cold air at night, much more acute local differences may develop than was formerly appreciated, and indeed it is not unknown yet for the Meteorological Office to ask for confirmation of some of the more extreme differences due to this cause at low-lying inland stations, especially when there is a snow-cover encouraging outward radiation but hindering conduction from the ground below. The flanks of a single valley may be subjected on a spring night to killing frost, damaging frost, or no frost at all. Much depends on the characteristics of the valley and its trend, whether it has a sizeable stream at the bottom, whether it is wooded, and whether it is narrow and winding or broad and open; and there is much to be done in this field by geographers interested in local climate and land utilization.

Where local stations are lacking, some estimate of the prevailing conditions may be made by comparing the records elsewhere. In England the most remarkable effects are on the floor of a narrow dry valley near Rickmansworth. These have been described in some detail in two papers by E. L. Hawke [1]; the average minimum temperature is below the freezing-point from mid-November to early April and is closely comparable with that recorded in the

[1] E. L. Hawke, *Q.J.R. Met. Soc.* 59 (1933) 261, and 70 (1944) 23.

Scottish Highlands at Braemar. Indeed it is not unusual for the minima in this valley to be from 15° to 20° below those recorded at Kensington, 17 miles distant; and frost of some severity has been recorded in each of the summer months. Phenomenal ranges of temperature have often been recorded. However it is justly argued that such conditions appertain only to the bottom of a dry-floored winding valley, and are unlikely to be found elsewhere.

Little has yet been done to discuss more representative records from the *Monthly Weather Report*, probably because one must know the characteristics of each reporting station. There is a further difficulty attendant, especially with regard to minimum temperatures, namely, differences in the hour at which minimum thermometers are read and set for the next day. It will readily be seen that in a month such as January average minima based on readings once daily at 9h. will be lower than those based on reading and setting at, say, 21h. For suppose that there is a single intensely cold night followed by mild weather; the temperature read and set at 9 a.m. will differ but little from the minimum on the cold night; but the same 9 a.m. reading will also be recorded as the minimum for the succeeding twenty-four hours. Thus the effects of a single intensely cold night will appear twice in the list of minimum temperatures from which the averages are derived, and this appreciably affects the published winter means. Average maxima are little affected. Lastly, the records at many stations are too short for accurate comparisons to be made, while at others small changes in the location and exposure of instruments may have been necessary.

Nevertheless, the distribution of stations has been close enough in certain districts for some effective discussions, notably in the neighbourhood of Edinburgh and Nottingham,[1] where the differences in the readings at adjacent stations can not only be related to the topography but are also partly affected by urban exposure.

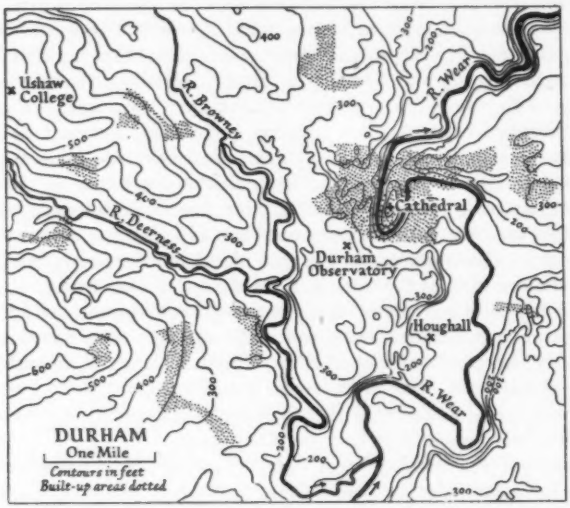
It remains to review some of the results from stations in representative hilly districts not subject to urban effects. I believe that the probable incidence and intensity of frost can largely be deduced by comparing from the reports not merely the average daily minima, but the average extreme minima for each month. These of course are in general the consequence of radiation conditions on a clear calm night at all times of year, and the resultant differences from place to place are not only remarkably consistent, but are often startling in their magnitude.

Some examples from the basin of the Middle Wear

Three stations are available in the neighbourhood of Durham. Here the river Wear has incised its course within the broad basin flanked by the rising spurs of the Pennines to the west, and the East Durham limestone upland (averaging 500–600 feet) to the east and south. Hence while Durham Observatory (336 feet) stands on the crest of a breezy, well-exposed ridge rising sharply 200 feet above the incised valley, it is still below the level of the rim of the basin. Three miles to the westward, Ushaw College records air temperature in a large, moderately sheltered garden on the crest of a higher

[1] Edinburgh: M. T. Spence, *Q.J.R. Met. Soc.* 62 (1936) 25. Nottingham: A. B. Tinn, *Q.J.R. Met. Soc.* 64 (1938) 391.

ridge (594 feet) from which the land falls on all sides. One mile south-east of the Observatory, the county agricultural station at Houghall (160 feet) occupies part of the broad extensively ploughed floor, here about a mile wide, of the incised valley; and undoubtedly it lies in one of the best developed frost hollows in the north. For example, on the same night in February 1941



the minima at the three stations were respectively 14°, 19°, and 3°. In Table I the average daily maxima for each month are also given as a matter of interest; it will be seen that they are reasonably consistent with the differences in altitude.

TABLE I

Average daily maxima (A) and minima (B), and average extreme monthly minima (C) for three adjacent stations, Ushaw (594 feet), Durham (336 feet), Houghall (160 feet). Period: 1925–40.

A	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Ushaw ..	42·4	42·6	47·3	50·8	56·5	63·0	66·6	66·5	61·1	53·2	46·8	42·4
Durham ..	43·1	43·7	48·3	51·6	57·1	63·7	67·8	67·2	61·9	54·7	47·9	43·1
Houghall ..	44·0	44·7	49·3	52·5	57·9	64·7	68·6	68·1	63·0	55·7	48·8	43·9
B												
Ushaw ..	32·6	32·9	35·3	37·7	42·3	47·2	51·8	51·1	47·5	41·8	37·3	33·9
Durham *	32·7	33·2	34·9	37·4	41·6	46·7	51·5	50·9	47·0	41·2	37·1	33·9
Houghall ..	31·1	32·0	33·7	36·8	41·0	46·4	50·9	50·0	46·0	40·0	35·6	32·1
C												
Ushaw ..	23·2	23·8	26·3	29·2	32·4	38·5	44·5	43·7	38·3	31·3	28·8	25·2
Durham ..	20·9	21·5	24·1	26·6	29·2	36·5	41·6	40·3	35·6	29·1	25·9	23·5
Houghall ..	16·9	18·6	20·3	23·8	26·4	33·3	39·2	37·3	31·7	26·6	22·7	19·7

* Observations at Durham refer to different terminal hours (21h. not 9h.).

But the average daily minima tell a very different story; throughout the year Houghall is on balance cooler at night than Ushaw on its ridge, and if

we take the average extreme minima as representative of conditions on clear quiet nights, the difference on such nights averages nearly 6°. In exceptional circumstances with a widespread and deep snow-cover, the difference has frequently exceeded 15°. Table I shows that the interval between the last frost in spring and the first in autumn is probably about six weeks shorter in the valley than on the ridge.

Intermediate conditions prevail at Durham Observatory, as the average extremes show. The average daily minima (B) at Durham are not strictly comparable with those at the other stations, on account of difference in terminal hour of observation; if Durham were to use the same hours as Houghall and Ushaw the figure for the three winter months (Nov.–Jan.) would probably be lower by something of the order of 0°.5; for the rest of the year the differences from this cause are probably smaller.

Such conditions are probably found in all incised valleys where the floor is wide; remarkably low minima are known to occur on Edenside, and those at Usk, a few miles inland from Newport, are noteworthy. Attention was drawn long ago to remarkable minima in parts of Yorkshire.[1]

A broad river, unless it is frozen, has probably a slight mitigating effect on the severity of frost close to its banks, owing to the slight surface turbulence resulting from the temperature difference between the water and the adjacent land. Lakes no doubt give rise to similar effects on their shores; among our official stations Keswick appears to give night minima slightly above those which might otherwise occur, except on the rare occasions when the lake is frozen; but no nearby stations as yet afford adequate data for comparison and assessment of the ameliorating effect due to this cause.

Minimum temperatures in Worcestershire: Thermal Belts

Worcestershire provides at Malvern a clear-cut example of other factors influencing the incidence and severity of frost. Two stations are available 9 miles apart, using the same observing hours and showing remarkable contrasts. Records have been kept 2 miles north-north-east of Worcester since 1926, at Perdiswell (94 feet) in open fields adjacent to an orchard and a large gently undulating park, about 1½ miles east of the Severn, and 50 feet above it. This station can thus be regarded as representative of the lower-lying parts of the broad Severn lowland, other than a narrow strip beside the banks of the river itself. Five miles to the north-east, Droitwich (106 feet) also provides a short record from a tributary valley, which so far appears to indicate a slightly greater liability to frost than at Perdiswell.

The Malvern station however (377 feet) is a little below the main road along the east slopes of the narrow range of the Malvern Hills; it frequently lies above the Severn valley mists, as is well shown by the winter sunshine record. Air drainage on radiation nights is only from a narrow ridge. Some allowance should perhaps be made for the warming of an eastward-facing slope by the morning sunshine. The results are rather remarkable; Malvern clearly affords a small-scale English example of the Thermal Belt conditions well known and described in the Southern Appalachians.[2]

[1] F. R. Stow, *Q.J.R. Met. Soc.* 5 (1879). E. H. Geake, *Met. Mag.*, 1926.
[2] R. Peattie, 'Mountain geography,' Harvard, 1936.

TABLE II

Average daily minima (A) at Perdiswell, near Worcester (94 feet) and Malvern (377 feet), and average extreme monthly minima (B), 1926–40.

													Mean Difference
A	*J.*	*F.*	*M.*	*A.*	*M.*	*J.*	*J.*	*A.*	*S.*	*O.*	*N.*	*D.*	
Perdiswell	33·4	33·7	34·9	38·5	43·1	48·3	52·5	51·6	47·6	41·6	37·6	34·2	
Malvern	35·3	35·5	37·4	40·7	45·4	51·1	55·4	54·8	51·2	44·8	40·2	36·1	+2·6
B													
Perdiswell	20·8	22·4	22·3	26·1	30·9	37·1	41·7	40·4	33·0	26·6	23·9	21·1	
Malvern	23·9	26·6	26·8	32·4	36·6	44·3	48·9	47·8	42·0	34·4	30·9	24·9	+6·1

The average extreme monthly minima (B) figures indicate the difference of temperature likely to be associated with clear calm nights. Evidently Perdiswell must expect a night with frost in May, whereas there is a fair chance that Malvern will remain above 32° in April. Perdiswell has almost an even chance of a night minimum below 32° in September, whereas Malvern commonly does not experience one till early November. The advantages of the higher level are thus manifest, provided that air drainage is not from an extensive upland. For there is a marked difference between the incidence of frost at Malvern on a relatively steep slope below a narrow ridge, and a former station in the same district which was maintained for some years at St. Michaels (313 feet) 2 miles south-south-west of Tenbury, on ground sloping very gently northward to the narrow Teme valley in which Tenbury lies. Average daily minima and also the extremes at St. Michaels were generally slightly above Perdiswell, but were still well below those on the favoured slope at Malvern (by 2°4 over five years, compared with 2°6 as given for Perdiswell above).

The advantages of location even on a northerly slope, compared with an upland valley at the same level, are also well brought out in the neighbourhood of Edinburgh. South of the city, Boghall (639 feet) and Balerno (750 feet) on the flanks of the Pentlands are both, judging by short records, appreciably less subject to severe extremes than West Linton (820 feet) near the floor of a broad open valley with almost negligible gradient, a few miles to the south.[1]

Incidence of minimum temperatures on and near the sea coast

Yorkshire.—That the extremes of frost may be mitigated by choosing a position on a relatively steep slope without an extensive plateau above, can be illustrated by comparing the records from Scarborough and Bridlington. The Scarborough record (118 feet) is kept little more than 200 yards from the sea, at the top of the St. Nicholas Gardens which fall steeply seaward immediately to the east of the station. The buildings of the town itself probably hinder the drainage of air from the land; and Scarborough rarely reports severe frost. By contrast, at Bridlington, over ten years, the average daily minima appear to be 2°6 below Scarborough, the average extreme monthly minima are 5°0 below; on five occasions in ten years the difference exceeded 10°. But the Bridlington record is kept (76 feet) nearly a mile from the sea,

[1] Cf. also W. R. Day and T. R. Peace, "Spring frosts," *For. Comm. Bull. Lond.* 18 (1937).

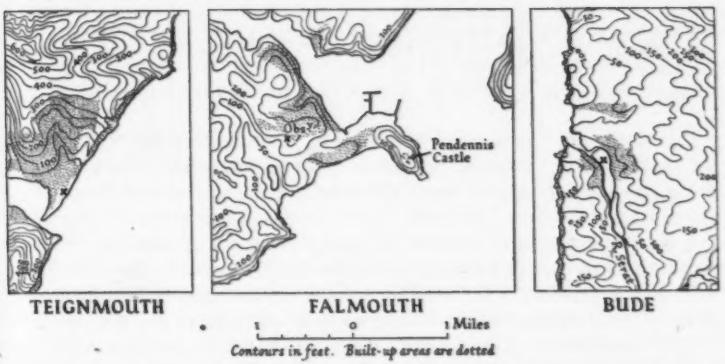
on the western outskirts of the town near the foot of a long stretch of the open Wolds, from which air drainage can take place freely especially when they are snow-covered in winter. Accordingly the Bridlington record indicates a liability to frost almost equal to that of an inland station.

TABLE III

Differences between the average daily minima (A) at Scarborough and Bridlington, and the average extreme minima (B): taken over 9–10 available years. Bridlington *below* Scarborough by:

													Year
A	1·6	2·2	2·3	2·3	2·2	2·3	2·5	2·5	3·3	4·2	2·8	2·4	2·6
B	5·8	3·4	3·9	3·3	4·4	6·7	4·3	5·9	6·3	5·0	5·2	5·8	5·0

On many British coasts amelioration of the night temperatures in cold weather is confined to a very narrow strip, especially where there is an uninterrupted gradual rise to extensive high ground at some distance inland; Cockle Park in Northumberland (325 feet) lies only 4 miles from the coast, and is not a valley site, but, like Bridlington, often gives minima comparable with stations much farther inland. With coastal resorts it is evident that allowance must be made not only for local features and distance from the sea, but also for the general character of the country inland.



Devon and Cornwall.—The frost risks near our south-western coasts are of special significance and the records from almost every station may be analysed with some profit, bearing in mind the period and length of record and terminal hours of observation. It is proposed here merely to note stations at which the effect of particular physical features is apparent.

Sidmouth, Teignmouth, and Bude may be compared: these three stations use the same observing hours, and stand 25, 20, and 49 feet above sea-level. Sidmouth lies at the mouth of a short and relatively constricted valley leading inland bordered by hills of somewhat limited summit extent. It gives in general distinctly lower minimum temperatures on clear nights (by 1°8) than at Teignmouth, which also lies on a small peninsula about a quarter of a mile wide at the foot of slopes below the relatively narrow crest of the Haldon Hills, and adjacent to the broad water inlet leading inland, of the Teign

estuary. Bude lies at the mouth of a valley draining a shallow basin several miles in width, which rises gradually to north, east, and south, and appears to be favourable for air drainage from the extensive Devon–Cornwall plateau. The station is in the centre of the valley, on top of a hillock about 40 feet above the river Strat itself. The average extreme minima at Bude are 2°5 lower than those at Teignmouth, and are therefore as a rule lower than those at Sidmouth in spite of position on the hillock.

The incidence of frost at Torquay resembles that at Teignmouth; and a brief record at Seaton, at the mouth of the Axe, which is a wider, longer, and less constricted valley than that of the Sid, indicates so far that Seaton is again appreciably more liable to frost than Sidmouth.

Table IV

Average daily minima (A) and average extreme monthly minima (B) at Teignmouth (20 feet). A, 1906–20, 1926–35. B, 20 years, 1920–39.

A	..	38·5	38·4	38·9	42·2	47·8	51·9	55·6	55·8	52·4	47·5	41·7	39·9
B	..	28·8	30·1	29·4	33·9	38·7	44·5	48·4	47·9	42·5	36·5	31·1	29·3

Average departures of A and B for Sidmouth *below* the figures for Teignmouth (10 years between 1929–40), and of B at Bude (10 available years since 1919).

													Year
Sidmouth below	δA	1·3	1·4	1·0	1·2	1·5	1·4	1·3	1·1	1·0	1·1	1·1	1·4	1·3
Teignmouth:	δB	1·8	2·0	1·5	0·6	2·3	2·9	2·2	2·5	1·4	1·9	1·4	1·2	1·8
Bude below Teignmouth:	δB	0·0	3·4	1·8	2·3	2·7	4·1	3·1	2·4	2·6	3·3	2·3	2·3	2·5

Falmouth and Fowey may be compared, farther down the coast. Fowey (51 feet) resembles Teignmouth in that it lies relatively low, by a water inlet, and it appears to have very much the same average extremes as Teignmouth in the winter months. Falmouth Observatory however keeps its record 167 feet above the sea, on the western margin of the town about a mile from the sea, but also on a slope falling away rather sharply to the south-west. Hence Falmouth appears to be appreciably warmer on clear nights than Fowey (by about 2°), and its records can be regarded as representing the advantages of "slope" position near the Cornish coast. Even greater freedom from frost is given by the other station near Falmouth, on Pendennis Head (200 feet), a headland from which the ground slopes sharply on three sides to the sea, and on the fourth towards the town itself. The Pendennis station is about 1^1_4 miles east of the Observatory mentioned above, and while the averages are not strictly comparable on account of difference in observing hours, a few years' records indicate that the extreme minima in winter are above those at Falmouth Observatory by about the same amount as those at Fowey are below. The recently established "headland" station at the Lizard also appears to resemble Pendennis.

Thus freedom from frost is again most evident on and adjacent to the slopes of isolated hills, as in Worcestershire; and the nearer the hill lies to the sea, the better. Valleys and basins are more frosty, depending again on the degree to which the relief and other factors permit air drainage from extensive uplands inland.

TABLE V

Average daily minima (A) and average extreme monthly minima (B) at Falmouth (167 feet). A, 1906–20, 1926–35. B, 20 years 1920–39.

A	..	39·9	39·5	39·9	42·5	47·7	51·6	55·2	55·4	52·8	48·1	43·2	41·1
B	..	31·1	31·2	30·7	35·3	39·5	45·4	49·8	49·1	44·5	38·3	34·3	31·6

Average departures of A and B for Fowey *below* the figures for Falmouth (15 years between 1925–40), and of B at Pendennis *above* the figures for Falmouth (1922–32).

													Year
Fowey	δA	0·9	0·8	1·0	0·6	0·5	0·7	0·6	0·8	0·8	1·0	1·0	1·1	0·8
below Falmouth:	δB	2·1	1·1	1·4	1·3	1·2	1·9	3·2	2·1	3·1	2·9	2·9	2·1	2·1
Pendennis above Falmouth:	δB	2·4	1·5	2·2	0·8	0·9	1·2	0·3	0·6	1·6	2·4	2·0	1·8	1·5

Criticisms may well be advanced against the validity of these coastal comparisons. One is, that the differences are so small that the presence or absence of buildings and shrubs adjacent to the screen may well affect stations more than the relief and other characteristics of the surrounding country. But the majority of official records are kept in acceptable enclosures reasonably distant from buildings and over short grass, and the choice of stations in this paper has been made with a view to well-sited instruments at which topographical features are likely to play the larger part in any existing differences. The average monthly extremes have been taken for periods of varying length, sometimes on account of interruptions in the published records, or slight changes in position of stations.

The effect of differences in soil

The most extreme minima are generally recorded after a calm clear night with dry air (*i.e.* a low relative humidity) and a deep snow-cover; in such circumstances temperature in inland valleys may fall well below zero. Snow-cover is important in that it forms a good radiating surface while at the same time it is a poor conductor of warmth from the ground. Sand however is also a poor conductor, and over dry sandy soils the air is liable to greater extremes of temperature than over loams or clays. In the day-time however the air is generally in motion and the average maxima over sand are not much affected.

Few places in England afford opportunities for this kind of comparison; South Farnborough and Wokingham have both attracted some attention in the past. Latterly a station has been established by the Forestry Commission on the Breckland in south-west Norfolk, at their nursery at Lynford, 6 miles north-north-west of Thetford. Eight years' records have been used and give some startling results, particularly when it is remembered that Lynford (99 feet) is not in a hollow and therefore, according to local report, does not record quite the lowest temperatures to which the Breckland is subject; a feature also indicated by some measurements of grass minima made in the neighbouring hollows and described by Day (*Q.J.R. Met. Soc.* 1937). Partial comparisons can be made with Mildenhall, 12 miles south-west on the edge of the Fenland, but the observing hours are not the same. Cambridge (University Farm, 78 feet), although more distant, uses the same hours and is representative of the East Anglian countryside; like Lynford, it is on

slightly rising ground. At the other side of Cambridge, the minima in the Botanic Garden (41 feet) tend to be a little lower than at the Farm by about 1° on clear nights.

That the differences between the Breckland and elsewhere on calm clear nights are primarily due to the dry sandy soil is well shown by the fact that in snowy weather with a continuous cover the minima are everywhere much the same, away from the coast or such valleys as that of the Colne and Stour. Startling differences can be quoted for several days during the dry cool anticyclonic weather of May 1941:

TABLE VI

Examples of maxima and minima at Lynford and Cambridge, May 1941.

	May 4	8	9	10	11	16	18
Lynford	59, 15	50, 18	53, 19	54, 17	58, 15	60, 24	69, 27
Cambridge (Univ. Farm)	57, 28	48, 30	49, 29	52, 29	61, 27	60, 31	68, 38

If the average minima over a whole month, including cloudy and windy nights (probably nearly half the total) as well as those which prove clear and calm, is, say, 3° below that at Cambridge, any clear calm night on the Breckland is likely to give a minimum 6° or more below, even over relatively flat country. This is the same order of differences as that found in the bottom of incised valleys, such as the Wear Valley at Houghall, or between Perdiswell and Malvern; although it is not so great as the difference found in very exceptional exposures such as the dry valley near Rickmansworth.

TABLE VII

Departures of the average daily minima (A) and average extreme monthly minima (B) at Lynford (99 feet) *below* those at Cambridge University Farm (78 feet), 1933–41.

											Year
A	..	2·2	2·5	2·6	2·7	3·1	3·1	3·1	3·7	2·8	2·4	1·9	1·9	2·7
B	..	6·0	6·1	5·8	6·8	6·1	7·5	6·6	7·6	6·1	5·9	4·7	5·4	6·2

These remarkable differences due to sandy soil are worth putting on record, as the growth of the Forestry Commission's plantations in the neighbourhood may in time have unforeseen effects, and the observations have for some time been discontinued. There is evidence that the prevailing vegetation cover may also affect the minimum temperatures recorded, for example, they are commonly lower after a calm clear night over long rough grass than over short grass (Cornford, *Q.J.R. Met. Soc.* 64 (1939) 553).

Some further results of urban environment with regard to frost

The general climatic effects in a great city such as London are well enough known, and have been summarized by Bilham, 'The climate of the British Isles.' Quite noteworthy temperature effects occur in the neighbourhood of smaller cities, notably Edinburgh and Nottingham (referred to above). In both these cities however the differences of temperature are also associated with relief: the two Birmingham stations also show interesting differences largely arising from this cause.

Manchester however covers an area more uniform in its relief than the

other smaller cities and has provided in recent years two city records of great interest; that at Oldham Road (191 feet), about 1^1_4 miles north-east of the Town Hall, lay in an open yard (about 60×40 yards) in a densely built-up area and is best known for its appalling sunshine record, about 30 per cent. below the surrounding country. The other station (125 feet) is in Whitworth Park, 1^1_2 miles south of the Town Hall and 16 acres or so in extent; it lies near a small lake, and built-up areas surround the park on all sides. Seven miles west of the city centre Barton airfield (70 feet) lies well outside the built-up area adjacent to Chat Moss in the wide flats near the lower Irwell. For a few months a record was kept at Alexandra Park (99 feet), 2^1_2 miles south of the city centre, and another covering seven years at Swinton (253 feet) on the crest of the gently-sloping ridge on the western outskirts of Salford, 4^1_2 miles west-north-west from the centre of Manchester. The sketch-map (p. 256) illustrates locations. To all these can now be added a record from Burnage (147 feet), a typical garden suburb area 4^1_4 miles south-south-east of the Town Hall.

Using Whitworth Park as a standard for reference, the following averages are found:

TABLE VIII

Average daily minima for each month (A), and average extreme monthly minima (B) at Whitworth Park (125 feet), Manchester.

A (1906–35)	36·2	35·6	36·7	39·7	45·6	50·1	53·7	53·1	49·4	44·4	38·7	36·9
B (1920–39)	24·8	26·0	27·5	30·9	34·7	41·5	45·7	43·7	38·9	31·6	27·3	25·8

Average departure of A, B at Oldham Road *above* Whitworth Park (10 years between 1928–38):

													Year
δA	..	1·3	1·6	1·2	1·1	1·5	1·8	1·9	2·2	2·2	1·9	1·6	1·6	1·7
δB	..	1·8	2·3	2·1	2·3	2·3	1·9	4·0	3·1	3·4	3·4	2·6	3·0	2·7

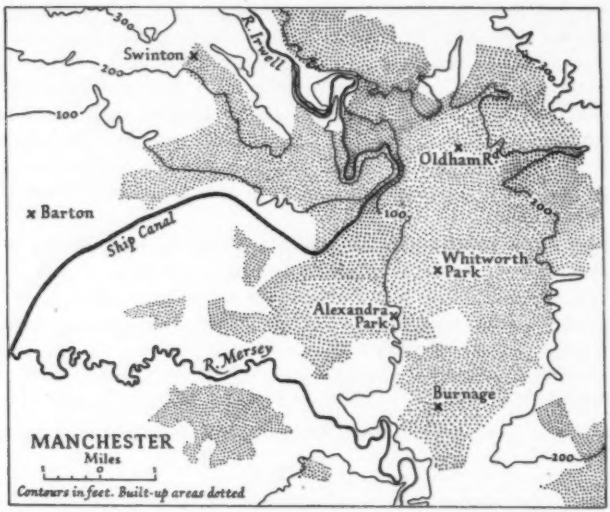
Average departure of B at Swinton (253 feet), Burnage (147 feet), and Barton (70 feet) *below* Whitworth Park:

													Year
Swinton δB (1925–32):	1·9	1·9	1·1	1·4	1·1	2·0	0·1	0·1	0·4	−0·3	0·7	1·1	0·9
Burnage δB (1934–41):	1·2	2·0	2·3	1·3	2·0	2·5	0·6	2·4	3·6	1·8	2·2	2·7	2·1
Barton δB (1934–40):	5·6	4·0	4·4	4·3	4·2	5·7	7·2	6·8	6·7	5·5	4·7	4·3	5·3

The average departure of B at Alexandra Park (99 feet) during 1920–21 was 4°7 *below* Whitworth Park based on a single year's record; this departure is of the same order as at Barton.

The departures δB at Oldham Road, Swinton, and Barton above are likely to represent the prevailing difference of temperature on clear, quiet nights between a city station in a small park, and others in the densely built-up area nearer the centre and in the outer suburbs. Swinton, on its ridge, lies in a partly built-up area on the outskirts of the city; it differs little from Whitworth Park in the summer and actually shows, on a rather brief record, a slight tendency to be warmer than Whitworth Park in autumn. But the most noteworthy effects are shown by Barton, little below the level of the other stations, yet its minima on quiet clear nights are likely to range between 6° and 8° below those at Oldham Road in winter and spring, rising to 10° in summer; presumably this is due to the radiation from buildings warmed during the day by the sun. Further, the brief outer-suburb record at Alex-

andra Park, little more than a mile from Whitworth Park, indicated similar departures in monthly extremes to those at Barton, in a year (1920–21) when the Alexandra Park area was less built-up than now. With regard to the short record (1934–41) from Burnage (147 feet), a typical modern suburban area with extensive gardens, $4^{1}/_{4}$ miles south-south-east of the city centre, it is interesting to note that the departures of the minima on clear nights are almost exactly intermediate between built-up and open areas.



Hence it would appear that the Barton temperatures are reasonably representative of the low Manchester plain before the building of the city, and thus a fair estimate of the effect of widespread building can be obtained. At the same time the other brief semi-urban record from the Swinton ridge indicates that the minima in a position 180 feet above the Irwell plain are likely to average about 3° higher on clear winter nights. This figure is of the same order of magnitude as those found with similar differences of elevation elsewhere, *e.g.* in the Nottingham district.

Freezing temperatures do not as a rule occur in May at Whitworth Park, whereas they must regularly be expected at Barton. The difference in the average extremes at this season due to urban surroundings is indeed comparable with that between Malvern and Perdiswell, or Ushaw and Houghall, due mainly to relief; it is also closely comparable with the difference between Lynford and Cambridge due mainly to soil.

Some of the above results may be illustrated by means of a diagram. If we assume that the average extremes likely to occur in any month are applicable to the middle of the month, we can plot the curves in Fig. 1. This assumption is manifestly imperfect, but will serve to show in a rough and ready manner the varying length of the interval likely to be free from damaging frost in different exposures. The curve C (normal lowland) represents the average

monthly minima for lowland stations in the English Midlands; it is chiefly based on Cambridge, Perdiswell, and Barton. Average monthly minima at Durham are however very similar; those at Oxford tend to be slightly higher. The curves A, B, D and E represent the probable trend of the average extremes in special circumstances; they have been drawn taking into account the differences between Oldham Road and Barton, Lynford and Cambridge, and others already discussed. It will at once be seen that a normal lowland station can expect its last screen frost in an average year towards the middle of May, while there is a likelihood that the first autumn frost will be about the

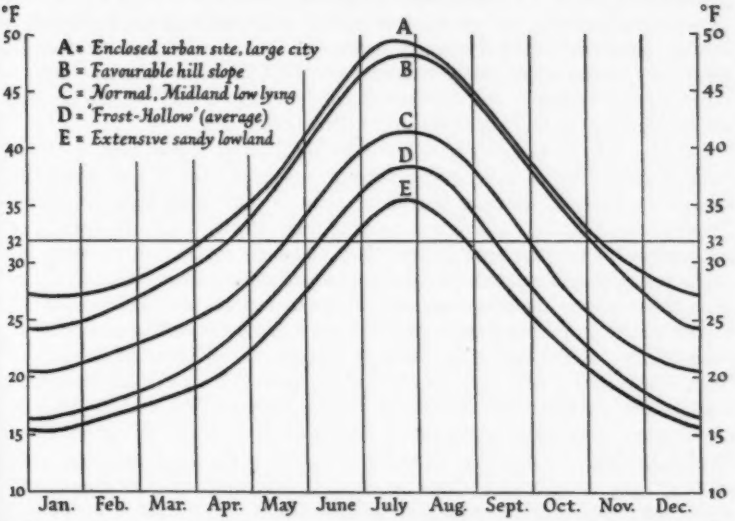


Fig. 1. Estimated trend of average monthly minima, English Midlands. Approximate interval between damaging frost for different types of exposure: A, April 5–November 5; B, April 15–November 1; C, May 15–October 1; D, June 5–September 12; E, June 20–August 25

beginning of October. On a favourable hill slope, to judge from Malvern, this period is about eight weeks longer; on an extensive sandy lowland, there is an even chance that freezing temperatures will occur as late as the middle of June and before the end of August, so that the average frost-free season is of the order of eight weeks shorter than at normal lowland stations.

Conclusion

Throughout this discussion the emphasis has been on the incidence of snow, snow-cover, and low night temperatures including frost, largely because the occurrence of each in Britain is markedly affected by topographical features, including relief in its several manifestations, variations in the soil and vegetation cover, and in the extent of the artificial cover of buildings. Further, the figures repeatedly remind us that the normal range of the

minimum temperature on a clear night lies almost everywhere within a few degrees of the freezing-point during several months, so that relatively minor local features may determine whether places are subject to frost of damaging severity or not, and thus affect the potential utilization of land.

First, it would appear that over the greater part of England the difference between "favourable" and "unfavourable" sites is such as to imply a difference of the order of 6° in minimum temperatures on clear nights, and hence a difference of the order of six to eight weeks in the length of the interval between the last severe spring frost and the first in autumn.

Secondly, there is much room for further study of the problem of local climatic amelioration, such as was instinctively practised long ago in the walled kitchen garden of many a country house. For relative freedom from night frost may nevertheless imply exposure to wind in many districts, with a consequent lowering of the day-time maxima. Hence a study of the climatic effects resulting in built-up areas may afford useful data.

Lastly, a selection of data from the *Monthly Weather Report* such as I have made is imperfect, as many records cover very brief periods and minor but significant features affecting particular stations may have been neglected. Whatever may be the perils accompanying such efforts, the rough-hewing of the material must sometime be essayed; and I do contend that where, for example, the published extreme minima consistently depart in either direction from those at neighbouring stations, similar departures are likely to prevail on the majority of clear quiet nights and accordingly the station is worthy of investigation, as the data thus obtained afford a useful index of liability to frost. For it is only when we have adequately surveyed the existing abundant material that we can consider the remedies for imperfections such as those of distribution of stations, exposure of instruments, or hours of observation. Beyond the official material there is, too, a wide field for the geographer who, starting from such brief indications of local differences as I have outlined above, may embark on more detailed analysis either with the aid of additional stations, or by relating the causes of such differences whether in temperature or in numerous other climatic elements to other local factors or to varying types of weather. The more subtle qualities and modifications of the British climate are indeed worthy of study.

I should like to acknowledge the generous assistance of the Meteorological Office in providing certain figures and information regarding the location of stations, and to express my thanks for these and other opportunities to make this paper more complete.

DISCUSSION

Before the paper the PRESIDENT (The Rt. Hon. Sir GEORGE CLERK) said: The reader of the paper this afternoon, Mr. Gordon Manley, is a member of the Department of Geography at Cambridge. He has long promised us a paper on certain climatic conditions in England. For a year or so that paper has been postponed owing to the pressure of other work, and I am not sure that the paper he is now going to read is quite the same as that which he originally promised us, but inasmuch as it deals with the topographical conditions which locally assist spring frosts, of which we have recently had an example, as well as with the

distribution of snowfall in the British Isles, I am sure Mr. Manley has some interesting results to record and we hope for a discussion following the paper.

Mr. Manley then read the paper printed above, and a discussion followed.

Professor D. BRUNT (Imperial College of Science and Technology): I remember that in pre-war days there used to be held an Ideal Home Exhibition, but no indication was given as to where the ideal home should be located. That defect has been, to a large extent, put right this afternoon by Mr. Manley, who has given us an idea where the ideal home should be placed. I congratulate him on the good results he has derived from relatively few observations. Far too little of this type of work has been done, though the essential theory is so simple: the difference between different types of soil can be reduced to a few words. The surface temperature over level ground is controlled by the conductivity and the heat capacity of the soil. The lower these two factors, the higher will be the surface temperature by day, and the lower the surface temperature by night. For then the downward conduction of heat absorbed from the solar rays by day will be slow, as also will be the upward conduction of heat by night to replace the heat lost by long-wave radiation to the sky. Both the conductivity and heat capacity of air are low, much lower than those of the solid particles in the soil, or even of those of water. Hence, the more air there is in the soil, the lower will be its conductivity and heat capacity, and the higher will be its surface temperature by day and the lower its surface temperature by night. Replacing the air in the soil by water will increase conductivity and heat capacity, and minimize the variation of temperature by day and by night. An interesting illustration is yielded by the meteorological station at South Farnborough, which is located on sandy soil. If the records of the Meteorological Office for cloudless nights are examined it will be found that the fall in temperature between sunset and sunrise is greater at South Farnborough than at any other English station under similar meteorological conditions.

When the soil is covered by grass the night temperature of the air above it is lower than over bare soil, two factors being of importance; first, the evaporation of water from the grass, and secondly, the effect of the grass in trapping air and keeping it subjected to the cooling influence of the surface much longer than is possible over bare soil, which does not impede movement of the air to the same extent. The effect of grass on air temperature is decreased by mowing the grass, and keeping it short.

It appears in regard to this subject there is need for carrying out actual experiments in the field. Little has been done to ascertain what can be achieved mechanically in order to improve conditions. If the soil contains too much air some of the risk of frost can be overcome by replacing the air by water; in other words, by flooding the soil. A pretty series of experiments might be carried out along those lines.

A few years ago I had the opportunity to make observations in an orchard in which a part of the area had been very heavily sprayed until the soil was wet to a considerable depth, while the remainder of the area remained dry and dusty. The wetting was much greater than is achieved by normal spraying. The air temperature was measured above the dry and the sprayed soil, and it was found that so long as the surface of the sprayed soil remained wet the air temperature above it was lower than that over the dry soil, on account of the heat loss due to evaporation of the water. As soon as the surface of the sprayed soil had become dry, the night temperature was higher over the sprayed soil than over the unsprayed soil, on account of the persistence of the water beneath the surface.

I cite these observations simply as an example of the types of experiment which can readily be carried out and which have definite value as climatological studies.

Mr. LEONARD BROOKS (Vice-President in the Chair): I wonder whether Professor Brunt or Mr. Manley could tell me why all the apple blossom on my trees fell off while the blossom on the trees in the adjoining garden did not. I sprayed my apple trees and my neighbour did not.

Professor BRUNT: You may have grass under your trees, and he has not.

Mr. BROOKS: He has nothing under his apple trees. Under mine are potatoes which are just beginning to come up.

Professor BRUNT: If you wish to grow fruit successfully you should hoe the soil beneath and not allow anything else to grow on it. If you must allow grass to grow, cut it short. Fruit growers frequently forget that they should not let grass grow under fruit trees because the temperature over grass is definitely lower than that over bare soil, and the longer the grass the worse it is. You may have sinned in that respect. And there might also be a difference in aspect as between your trees and your neighbour's, or there may be a flow of air downhill into your garden and not into his.

The CHAIRMAN: We have Mr. Bonacina of our own staff with us. I hope he will contribute to the discussion.

Mr. L. C. W. BONACINA: Mr. Manley has emphasized the great importance of what he calls topography or, as I would prefer to say, land configuration. Climatically Britain is still but partially known. Meteorologists are often accused, and with a certain amount of justice, of drawing their isopleth curves across the map of Britain on insufficient evidence, especially across wild mountainous regions. But I think geographers can also be charged with interpreting those maps in an unimaginative manner. Theoretically it is not easy to select climatological stations well representative of the regions in which they are placed. Hence great care should always be exercised in attempting to draw mean isopleths across the face of this or any other country.

May I add a few words in regard to frost hollows. The fact is, of course, well known to all fruit growers. Nobody with any sense would plant an orchard at the bottom of a valley; neither would he plant it on the top of a hill, on account of the wind. The best position is probably under the crest of the hill, or halfway up. In these islands minimum night temperatures below zero Fahr. occur chiefly though not exclusively in frost hollows. In the very hard frost in January 1940 most of the sub-zero frosts were in the hollows; some of them may have been on the sand.

The question of frost hollows needs thorough investigation all over the country because not only does it depend on the relative height but also on the absolute height. The famous frost hollow near Rickmansworth just on the edge of the Chilterns on the chalk is a lowland depression. Are there not elevated valleys and ravines in the Scottish Highlands and in the Pennines where the Rickmansworth figures would be very much eclipsed? It is a really complicated matter.

The CHAIRMAN: The President asked me to tell Mr. Manley that his first map gave him confirmation of something he had always suspected, that the region in which his Scottish home was situated had more snowy days than any other part of the country. Is there any one else who would like to ask a question or to make any comments?

Mr. R. G. VERYARD: I found Mr. Manley's paper extremely interesting. As a meteorologist faced many times with the problem of forecasting fog, and this generally involves forecasting the minimum temperature, I feel that all fore-

casters should make a careful and detailed study of the immediate topography of their station, which I suppose most of them do. I take it that Mr. Manley when he talks of frost means screen frost. That should be made clear. I was surprised to see in some of the tables and curves that the differences are greater in summer months than in winter; one table showed this particularly, and in view of the short nights in summer it is puzzling. Perhaps Mr. Manley noticed that himself and has an explanation?

Mr. S. H. BEAVER: We should be extremely grateful to Mr. Manley, as representing a very small group of research workers in this particular field of micro-climatology. We have unfortunately lost by death, and a most serious loss it has been, one of Mr. Manley's fellow-workers, Dr. Matthews, of Bedford College. There are only a few others in the country. One other worker who shows signs of producing promising results after the war is Dr. Alice Garnett, of Sheffield. I hope when the lecture is published it will encourage post-graduate students in many of our university geography departments to take up this very valuable work on micro-climatology.

In these days I tend inevitably to think of things in terms of planning, and my mind was set wondering what planners can do about taking into account this subject of aspects and the details of climatological factors which we have heard described this afternoon. I feel that those in the north of England will have to go on grinning and bearing it, otherwise we shall have the whole population concentrated in London and the south even more so than at present, because the south of England seems on almost every count, except for sandy areas, to be a much more comfortable part to live in than Halifax and Huddersfield, or some of those other places which have fifty days' snow in the year and other unpleasant features.

When our architects and the others who really do the detailed planning of our housing estates, work out their schemes for the future, I hope it will be possible for them to have access to Mr. Manley's and other similar work, so that they at any rate know roughly what they are going to let the household gardeners in for.

Finally, a word on the title of the paper. Mr. Bonacina rather hinted that Mr. Manley's choice of the word "topographical" was not apt. I agree that if Mr. Manley had confined his attention to relief the title of the paper would have been incorrect, but since he has introduced topography in its proper sense (derived from the Greek *τόπος*, meaning "a place"), and since he has dealt with the climate of actual man-created places and not merely relief, then I think the title is correct.

The CHAIRMAN: Would Dr. Devik like to speak? He recently gave the Society a paper on "The formation of ice in lakes and rivers."

Dr. OLAF DEVIK: Arising out of Mr. Manley's interesting lecture it occurs to me that perhaps it would be possible to regulate, to some extent, the effects of cold air upon farms and gardens. Cold air of course floods, just as water in valleys, and it will have a tendency to collect in frost hollows. I wonder if the conflicting results on gardens and farms are due to hedges and walls conducting the flow of cold air from above to less favourably situated neighbours; it might be a matter of regulating hedges and walls and ditches and such things to influence the micro-climate of a particular garden or farm.

A FELLOW: I should like to associate myself with the last speaker's remarks. The lecturer laid more emphasis on the nature of the soil than on the slope of the ground. I think perhaps that frost on the ground is as much due to the direction of the wind as to the nature of the ground, and that if we were advising people where to build and what the risk of frost would be, then there is a good

deal to be said for a south-west slope protected from the northerly and north-east wind.

Mr. BONACINA: There is one point in regard to snow which will probably bear upon a question asked. The snow blows off the high ground on to the low ground, on the lee side. That is the explanation why houses and trains get buried in blizzards. I have heard country people ask where the snow on Dartmoor goes to. There is a tremendous blizzard and the moor is often left bare of snow, because the snow fills up the hollows which are hundreds of feet deep. Sometimes it is blown off the moor over the coast and out to sea.

Mr. GORDON MANLEY: As to Professor Brunt's comment on the possible effects of vegetation I feel that there is room for further exploration of the effect which might have occurred in this country through, for example, the marked extension in the amount of arable land in the eighteenth century; also the clearing of trees and the change from relatively coarse grasses to fine grasses. It seems likely that these might well have effected some slight amelioration of our climate.

Mr. Bonacina might be interested to know that I could mention at least two agricultural experimental stations which have been placed in quite well-marked frost hollows. At one, according to Dr. Stamp, the people ask: Why is it we find such difficulty in growing fruit here? At the other they are still wondering to what extent their fruit bushes are beginning to show signs of becoming more resistant to the climate than they were. These small variations have the effect of hardening quite a number of plants which have had to migrate to and fro about our island.

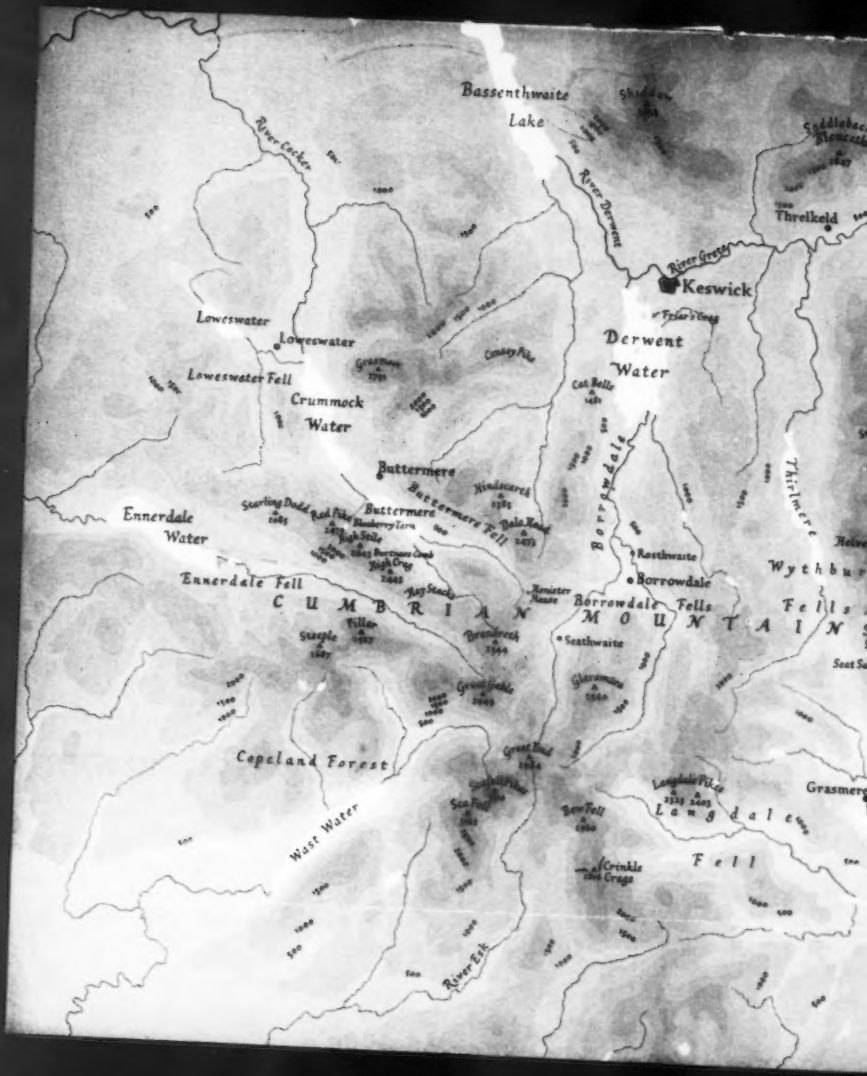
With regard to zero temperatures, I must quote to Mr. Bonacina a temperature of 1° below zero in 1881 at Blackpool, a place which is certainly not a frost hollow. I agree with the possibility of high-level frost hollows, and I feel that some enterprising Scotsman might put a station up at Glen Einich in the Cairngorms, a long flat-bottomed valley 2000 feet above the sea, which may provide interesting results.

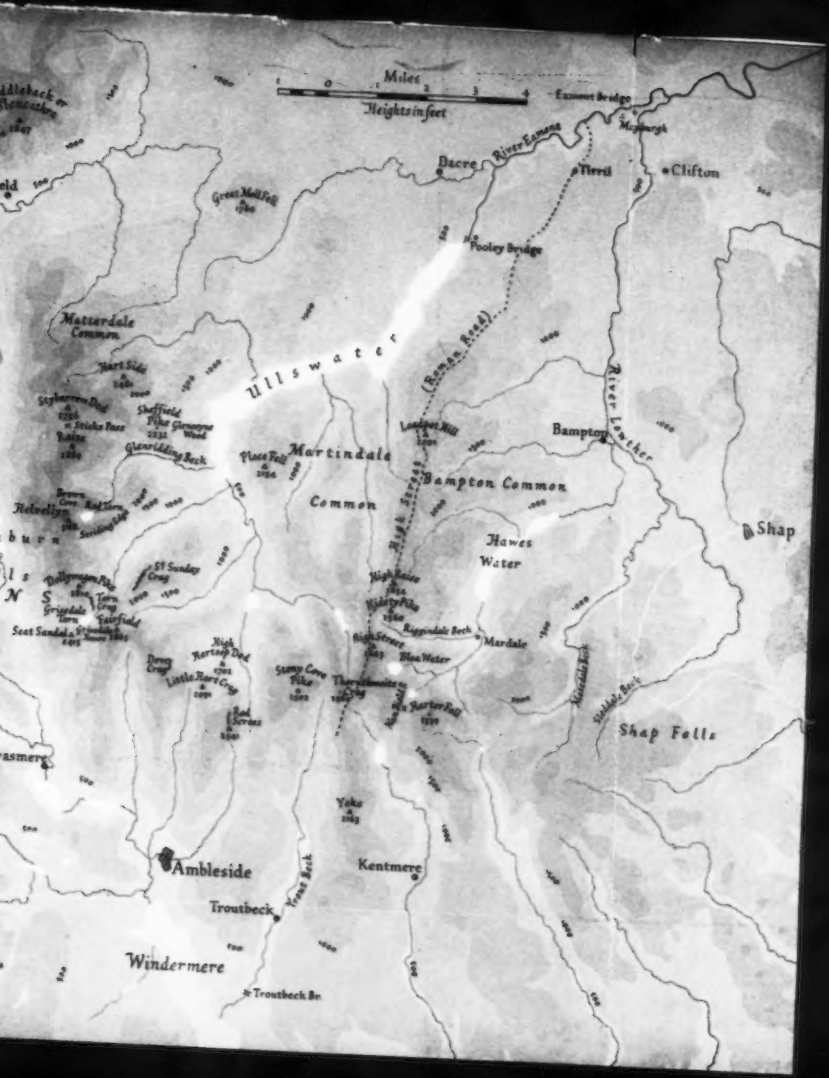
With regard to temperature differences being greater in the summer than in the winter although the nights are shorter, I think the figures relate particularly to those places where I was drawing a comparison between a country station such as Barton near Manchester and town stations which are well surrounded by buildings. Town stations in the summer would absorb on the sides and roofs of buildings rather more radiation by day and give it out at night, with the result that the differences of nocturnal temperature are often greater between built-up and country areas in summer than in winter.

I was trying to confine my discussion to screen frost, 4 feet above ground, and to disregard entirely the doubtful question of exactly what is ground frost.

In reply to Mr. Beaver, I feel strongly that there are certain advantages in the north of England climate which will prevent a large number of people coming down from there to the delights of London. I can only ask you to decide why it is that one can get out of a train in Halifax, a very smoky place, and yet not be able to deny that the place is extraordinarily bracing even for the east side of the Pennines. I do not know what relation that has to the old Yorkshire proverb: "Do business with a man when the wind is in the north-west." There are certain advantages in the frequent exchange of air in the north.

I was very glad to hear what Dr. Devik said. He drew attention to the possibility of the ponding of air against walls and hedges, and some work bearing on this was carried out at East Malling. We had a station at Garforth in Yorkshire some years ago which used to provide astonishingly low minima.


Bassenthwaite Lake
River Cocker
River Derwent
River Greta
Keswick
Threlkeld
Loweswater
Loweswater
Loweswater Fell
Crummock Water
Derwent Water
Buttermere
Buttermere Fell
Ennerdale Water
Ennerdale Fell
Borrowdale
Rosthwaite
Seathwaite
Borrowdale Fells
Wythburn Fells
Thirlmere
CUMBRIAN MOUNTAINS
Copeland Forest
Wast Water
Langdale Fell
Grasmere
River Esk


Miles
Heights in feet
Dacre
River Eamont
Tirril
Clifton
Pooley Bridge
Matterdale Common
Ullswater
(Roman Road)
River Lowther
Bampton
Martindale
Bampton Common
Common
Hawes Water
Shap
Shap Fells
Mardale
Blue Water
Ambleside
Kentmere
Troutbeck
Windermere

On investigation it was found to lie in a little frost hollow, but, speaking from memory, the thermometers had been placed too near to a barrier against which the air had ponded. You have a local factor there, and I think the Meteorological Office takes pains to have their stations so disposed that buildings or walls are at a considerable distance, so that it is possible to get a fair index of the local climatic conditions. I tried in the discussion to pick stations which seemed unexceptionable from this point of view; for instance, that at Sidmouth, which is in good open ground with plenty of open fields and recreation grounds nearby.

As to the last speaker's comments upon the advantages of south-western slopes I very much agree that they exist, but the station at Malvern lies on an eastern slope, and yet it would appear that there are advantages to be gained from the morning sunshine and the rapid warming up of the slope which probably effect the greater exposure to cold wind at some seasons of the year. Wind at temperature below freezing-point is confined to a very few months, during which plants are not likely to make any notable growth. An interesting instance is to be found outside Edinburgh, where even on a northern slope at six or seven hundred feet there is a certain climatic amelioration when compared with the observations only a few miles to the south but taken in open valleys rather than on slopes.

The CHAIRMAN: I am sure all will agree that we have listened to a most interesting paper and discussion, and we are very grateful to Mr. Manley for his paper and to those who have joined in the discussion.

MOUNTAIN FORM IN LAKELAND

THOMAS HAY

AMONG the countless people who are attracted by the natural beauty of the Cumbrian scenery, not a few are interested in the evolution of its outward form. I remember Dr. Marr calling attention to the fact that formerly there were many amateur geologists who did notable work in the development of that science but that nowadays the unprofessional worker had almost disappeared. This may be because geology has made such great strides that it has become almost completely the domain of the trained expert. Many of those who formerly would have taken the whole range of geology as their field of interest may in these later days confine their energies to the history of the surface features. It is hoped that some of these workers may find the following notes helpful in their studies.

Not far away from Lakeland there is in the Southern Uplands of Scotland a large tract of country in which the rounded forms of the mountain tops are noticeable. This rounding has been ascribed to ice action by the Scottish geologists. One would have expected that the history of these two closely situated areas would have been somewhat similar and that any process which produced a dominant feature in the one area would give rise to the same feature in the other. But the small part of Lakeland with rounded summit land has been attributed by Dr. Marr to a totally different cause. He thought that these parts of the Cumbrian hills, of high elevation and subdued slopes, were a remnant of the preglacial surface practically unaltered by ice action.

Generally speaking Dr. Marr's interpretation has been accepted by later English geologists and we are therefore faced by a major problem: how can two such divergent interpretations be true of two areas situated so close together? It was the feeling of doubt created by the two explanations mentioned that led me to make a careful examination of the summit land. The results are now given as they may have some interest.

I will start with a short analysis of the different types of scenery in this Lakeland area. The famous view from Friar's Crag on Derwent Water shows typical examples of the scenery of the Borrowdale rocks on one side and of the Skiddaw slate rocks on the other. Looking southward along the lake to the jaws of Borrowdale there is the wonderful variety of mountain outline resulting from the irregular erosion of the heterogeneous volcanic rock. Away to the west and north there is a landscape of Skiddaw slate and here the outlines are more regular, and the shapes of the fells may almost be classified. The long straight declivity and the evenly pointed peak are predominant features. It is a scenery of great beauty despite the hint of cubism. In fact, Skiddaw itself when viewed with Derwent Water at its feet or as a background to the view from Dale Head is as fine as anything in the Borrowdales.

Here then we have two different types of scenery so close together that they must have experienced practically the same later history. This shows what a vital part has been played in the development of the scenery by the character of the rock and its reaction to the influences of weather and ice.

The Silurian rocks lying south of the Borrowdales nowhere attain an elevation over 1054 feet and they give rise to a tamer scenery, though sometimes quite hummocky in its smaller features. Surrounding the whole area the foot-hills consist of a variety of different formations, *e.g.* Penrith sandstone, limestone, and basement conglomerate. All these rocks, later in formation but at a lower level now, have experienced the passage over them of ice sheets from other areas of sufficient size and power to modify their form and to develop roches moutonnées.

Any rocks that are sufficiently tough and with a suitable arrangement of joints may have the form of roches moutonnées impressed upon them by the passage of a heavy ice sheet. These roches moutonnées may be on the scale of a mere rock, a knoll, or a complete hill. In the latter case perhaps it may be regarded as the attainment of a form in which something like stable equilibrium has been reached for the time being. The struggle between the onward plucking movement of the ice and the resistance of the rock depending on texture and joint-spacing has resulted in a general curved surface of moutonnée type. Sheffield Pike to the west of Ullswater is a semi-detached part of the Helvellyn range (Plate 8). It lies exactly east of Sticks Pass and west of Glencoyne wood at an elevation of 2232 feet. It shows that a strong current of ice has passed right over the summit from the direction of Brown Cove lying to the north-east of Helvellyn top. There lies a little south-west of the summit cairn an exposure of rock which has been particularly vulnerable to the ice. A train of erratics has been dragged from this outcrop in a north-east direction past the cairn and one or two have been perched on the cliff overlooking Ullswater. The lee side of the outcrop is a small chaos, a mass of overturned boulders that the ice has disturbed but failed to carry away. The

whole area around this cairn is a most instructive example of ice erosion. The stoss side of this whole hill fronting the Helvellyn direction shows a general rounded outline when viewed from the Glenridding valley below, but yet it does not exhibit on its surface any rock glacially ground to the moutonnée shape. It is noticeable that this smooth rounding is developed in the valleys and on the lower slopes of the fells where the ice was deep and powerful. On the other hand the roughened surface produced by block removal is to be found as a rule at higher elevations.

The whole area may be classified into the following scenic types:

(1) The foot-hills where the rounded form is very noticeable and which may extend up to 1760 feet, the height of Great Mell Fell. Here the rounding may be attributed partly to ice action as they have been subjected to heavy ice attack.

(2) The great valleys running up to highland forming the shank of Marr's Caddy spoon. This lies on an east–west line stretching from Great Gable to High Street proper. These valleys are more regular in Skiddaw slate than in the Borrowdale rocks. They show the effects of ice action in their U-shape, their truncated spurs, and their hanging valleys. Most of them have lakes with deltas at the head.

(3) The rugged land lying between the valleys and leading up to the summit areas. It is exposed in the steep upper parts of the valley walls and on the uneven interfluvial tracts. In the central portion it reaches right up to the top of such mountains as Great Gable and Scafell Pikes. The whole of this rugged surface seems to be the result, direct or indirect, of ice action, *i.e.* of the plucking action of the ice and not the grinding action.

(4) The summit land is mainly of the same nature as No. 3. Hay Stacks, Place Fell, Glaramara, and many other mountains have a rugged and irregular surface which seems to be the direct result of the plucking and removal of blocks by ice action from a widely-jointed rock. But parts of the summit area have a gently sloping surface with rare exposures of solid rock and are covered with short vegetation and in places a layer of decayed rock which may be affected by solifluction processes. In outward appearance they are like elevated downs. Some of the westward-facing parts of Helvellyn, the whole of the Helvellyn Dods, and the long stretch of High Street form good examples of this subdued summit land. Dr. G. H. Mitchell, in his "Geomorphology of the eastern part of the Lake District" (*Proc. Liverpool Geol. Soc.*, 15, p. 78), has described an area of this type lying around the headwaters of Mosedale and Sleddale Becks. All these are examples of what Marr interpreted as relics of the preglacial surface.

(5) Lastly there are the combes or corries and the cliff walls that may be attributed in part to direct ice action and in part to frost action during and since the ice action. Helvellyn Red Tarn, Mardale Blea Water, the Pillar and Steeple Cliffs, and the Buttermere mountain wall all form good examples. Most of such cliff exposures face some point between north and east.

In my examination of the summit land, much of the area which I had already visited, I visited again, making a special search for erratics. The

evidence from erratics is patchy. Over wide areas where the action of ice is an absolute certainty no erratic can be found. But when they do occur and when no other method of transport can be advanced, their evidence is conclusive. In the case of these high-level erratics a great number can be proved to be short-distance local ones which have only been shifted through a small space.

From this examination three conclusions emerge: first, the rugged areas whether ridges, wider interfluves, or mountain tops are characterized by the presence of erratics. So many of these high-level examples have been mentioned in former papers that it is unnecessary to recapitulate them. It will suffice to mention the most spectacular. There is a train of boulders on High Stile at an elevation of 2600 feet crossing the top of the mountain in a north-north-west direction. In its transit, it rises over a slight elevation and then descends again; so that there is not the slightest doubt about the action of the ice. The light colour of the boulders makes them stand out in contrast with the rock over which they have been carried.

Secondly, the areas of subdued relief are characterized by the absence of erratics. This does not mean that no erratic is ever found on such an area. One or two have been found and photographed and probably others exist, but they are very rare. These two comprehensive results of the summit observations are a very strong argument for Dr. Marr's conclusion.

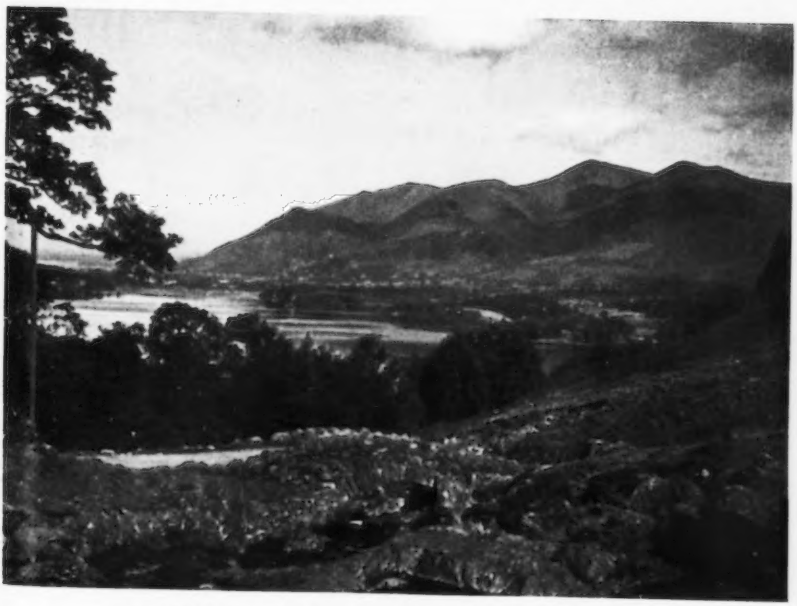
Thirdly, in some places on the subdued areas there is a thick deposit of local drift composed of a gravelly material which is the result of weathering in situ of the solid rock. A similar deposit occurs at the top of the Howgill Fells as Marr and Fearnsides have described. This suggests a long period of névé and frost action on such ridges as the Helvellyn Dods and High Street. Possibly for a considerable time they were covered during the colder period of the year and clear during the less severe part.

Rock contrasts

The difference between the reactions of Skiddaw slate and the Borrowdale rocks when acted on by weather and by severe ice erosion must be considered. There are other results of this difference in rock which cannot fail to be obvious to the student of scenery. Marr has suggested that hills of Skiddaw slate during the period of subdued relief before the ice age were more pointed than those composed of Borrowdale rock. This he attributed to the fact that the latter rocks are more pervious than the former and the streams are wider apart. Consequently there was time in the case of the Skiddaw slates, as streams were nearer together, for the interfluves to be reduced to ridges and the hills to peaks.

Although both types of rock were subject to the two highly different forms of ice erosion, plucking and grinding, owing to their different jointing the results were dissimilar. The Borrowdale rocks have widely spaced, well-developed joints and erosion has mainly been by the removal of considerable blocks. Owing to the general hardness of these rocks the erratics are long-lived. The Skiddaw slate, on the other hand, is generally free from large well-developed fractures, but has innumerable little closely-placed joints. It does not appear to have been much affected by plucking, but it has been removed

1. Head of Borrowdale from Rosthwaite–Watendlath path



2. Skiddaw and Derwent Water from Ashness Bridge

3. Rounded cap of Great Gable with rough foreground of Hay Stacks

4. Pillar from tarn on Hay Stacks, glaciated foreground with erratic extreme right

in small fragments which often form an extremely tough and tenacious boulder clay. The slates and grits of the Silurian area and the basement conglomerate, although it contains boulders of some size, react to ice attack like the Skiddaw slate type. The consequence of this reaction is that the Skiddaw slate fells show a remarkable freedom from erratics of their own rock. There are exceptions to this rule, especially when the Skiddaw slate has been metamorphosed into schist and thus acquired characteristics like a volcanic rock. There are many examples of Borrowdale erratics on Skiddaw slate, such as the well-known granophyre blocks on Starling Dodd or the Borrowdale erratics on the Dale Head to Hindscarth ridge. But, taken on the whole, the rule holds good that erratics of Skiddaw slate on Skiddaw slate at any considerable elevation are very rare while Borrowdale erratics on Borrowdale rocks are innumerable. This is not a result arrived at by contrasting a heavily glaciated area of Borrowdale rock with a more lightly affected part of Skiddaw slate. It can be proved by the examination of any typical area of the latter rock.

The difference in jointing between the Borrowdale and Skiddaw rocks leads to the difference in outline and skyline. A ridge in the Borrowdales such as Striding Edge or Crinkle Crags is a succession of irregularities with an uneven surface of bare rock. A ridge in the Skiddaw slate area such as the Grasmoor to Causey Pike stretch or the crest line of Blencathra is much more regular with steep but more even slopes and generally covered with close vegetation. Again, the Borrowdale areas have many hollows between projecting rocky knobs which are boggy in wet weather. The ground between Hay Stacks and Brandreth is a good example of this. It has all been severely glaciated as the moutonnée rocks, striations, and erratics prove. Besides the tarns lying in rock basins on Hay Stacks there are great stretches of the hollowed parts now filled with peat and bog. This type of mixed rocky and boggy ground is not found on the high-lying parts of the Skiddaw slate because both under weathering and ice action the even contours and regular slopes throw the water off without leaving boggy ground. In fact, the outlines of the Skiddaw slate fells illustrate a rule given in Marr's 'Scientific study of scenery': "When conditions are uniform and agents are acting with uniformity the results will be symmetrical." He was then talking of the excavation of river systems and the development of mountain ranges, but the principle applies equally well to the action of ice on a homogeneous rock. As a result of these rock differences the fell-top walker finds his progress much easier on the Skiddaw slate areas than on the more exciting Borrowdales.

The Ullswater Glacier

If some parts of the summit land still show the preglacial surface it would be natural to suppose that for a great part of the glacial epoch the ice cover consisted of separate flows which might be regarded as so many glaciers. In the case of the drainage area of the Ullswater depression there is on the west a range of subdued summit land stretching along the Helvellyn Dods and Hart Side and on the east a similar range along High Street. These certainly look like the wing boundaries of a large ice flow but no similar or continuous southern boundary exists. Mitchell thought that High Street was a very ancient ice divide and that Stony Cove Pike was a remnant of the subdued

land. The whole of the Red Screes to Fairfield ridge is characterized by ice erosion and by the presence of erratics. Even Fairfield although approximating to subdued summit land has erratics almost to the top and there are block spreads which have a remarkable resemblance to others in which short-distance erratics have been found. Still the summit is but slightly modified if at all and may be taken as part of our boundary. Fairfield forms part of R. B. McConnell's High Street Surface—the highest Lakeland surface that he describes in "Residual erosion surfaces in mountain ranges" (*Proc. Yorks. Geol. Soc.* 24, 1938 (1939) 76–98). But the whole of this ridge, Red Screes–Fairfield, must have been under the ice and subject to ice movement possibly changing in direction as the supply of ice varied between the two sides. The gap at Grisedale Hause was probably crossed by a flow of ice from the south-west, and this, increased by the mass occupying the Grisedale Tarn hollow to the east of Seat Sandal, supplied power to mould the fine U-shaped opening between Tarn Crag and the Fairfield–St. Sunday ridge. North of this gap the ridge of Helvellyn from Tarn Crag to Stybarrow Dod provides a mixed area. The south end at Tarn Crag and the north end at Raise are ice eroded, and Clifton Ward found erratics at both ends. But the middle part from Dollywaggon Pike to Helvellyn top shows by the smooth slopes on the west side and the general absence of erratics that it has been very slightly affected by the ice. A couple of erratics have been found on this elevated part, but they are quite rare. The great combes on the east side of Helvellyn have eaten right back to the highest point of the summit land, thus making the contrast between the almost perpendicular cliffs on the east and the smooth slopes on the west. A little farther north, Raise may be taken as the last point where ice action has had much influence on the summit land of this range. Just south of it the erratics noticed by Clifton Ward occur and just north of it the range of the dods begins.

The view from Dove Crag is interesting. On the skyline to the north-east there is the long smooth contour of High Street from Loadpot Hill to High Raise. Then follows in the same clockwise direction the more irregular bit by Kidsty Pike and the Straits of Riggindale. Erratics occur sparingly here and the Ullswater ice probably linked up with the Hawes Water glacier even after they became differentiated. Then comes the smooth contour of High Street proper, Thornthwaite Crag, and Stony Cove Pike. Nearer than this to the spectator the ground is all rugged from ice action. Looking now to the land inside that boundary and lying to its west one sees all the irregularities of the roughened land culminating in the mass of Place Fell (Plate 10). This is a typical example of the intermediate roughened land where some rounding occurs but where plucking action has been more important and where erratics occur without being numerous. The Ullswater glacier seems thus to be fairly well delimited at the time in its history when the Helvellyn range and High Street formed its west and east boundaries and when its south and south-west perimeter was under the general ice cap in that direction. South-west of Mayburgh on the road between Eamont Bridge and Tirril there is a transverse roll of ground with many Borrowdale erratics. This may be the farthest identifiable deposit from this glacier at a very much later stage of its existence.

In finding boundaries for this Ullswater glacier it will be noticed that much

5. Buttermere and Crummock Water from Green Crag on Warnscale rim

6. Sca Fell group in distance, Pillar centre, Steeple extreme right: from Red Crag

7. Smooth skyline of Stybarrow Dod on right, blockspread in foreground

8. Rough foreground of Sheffield Pike, Helvellyn left distance

of the subdued summit land has already been used. All the land claimed by some writers as belonging to this category is not admissable. For example High Hartsop Dod has been given, but this hill is only 1702 feet high and must have been subjected to great ice action from its very position. It forms the end of a ridge running up to Little Hart Crag and the whole ridge is noticeable for the presence of erratics. This hill seems to be clear evidence that rounded parts which at first sight look like examples of the subdued summit rounding are not incompatible with considerable ice action. Whenever the jointing conduces to the development of a firm resistant arched surface, or where the rock is inclined to react to ice action like a close-jointed rock, then the rounded form may be developed by ice action. With Skiddaw slate it must be remembered that by its very nature it tends to develop an even regular surface. So that a smooth surface and even contour is not necessarily an indication of absence of ice action or the presence of a preglacial surface.

The central area

The block of land between Thirlmere and Derwent Water is characterized by an irregular surface with many hollows and erratics. Its southern end forms the Langdale Pikes on Marr's caddy spoon axis. There is no trace whatsoever of subdued summit land. On the west we come now to the Glaramara ridge running down to Rosthwaite. It is a fine rough range of craggy rock with numberless erratics and every sign of intense ice action. Great Gable to the west with its rounded cap, covered with block spreads, rocky points, and few short distance local erratics looks like a remainder mass with even its top torn by ice but still showing the old shape (Plate 3). From it high land runs north to Cat Bells although it is crossed by Honister Hause. All the southerly part of this ridge lies in the roughened ice area and has block-spreads and erratics. The land between Borrowdale and the Buttermere valley is rather varied. At the south-east corner there is volcanic rock, but from Hindscarth to Grasmoor it is all Skiddaw slate. Grasmoor top, considering its elevation, its shape, and its lack of erratics may well be a portion of subdued remainder land but it has a great collection of drift on its north slopes. The block of land between the Buttermere and the Ennerdale valleys begins at the south-east in the ice-torn area near Brandreth and includes the delightful ridge from High Crag to Red Pike. The great combes of Burtness and Bleaberry Tarn on its north-east flank are part of a steep rock wall. The whole ridge has numberless examples of ice action, in particular the erratics on High Stile. The ridge widens out and farther north-west Starling Dodd and other Skiddaw slate hills have rounded contours. South of Ennerdale comes another great triangular wedge with its apex at Great Gable, its south-west margin on Wast Water, and its base on the Cumberland plain. Great Gable may be regarded as the hub of all this central area. West-north-west of it lie the equally grand rock mountains of Pillar and Steeple. The summit of the former of these bears some likeness to Great Gable top and looks like a bit of the original surface eaten at on all sides by erosion on the surrounding cliff faces. Farther on the ridge diminishes in height and gives place to rounded granophyre and then near to Ennerdale foot to rounded Skiddaw

slate hills. Still going anti-clockwise there comes perhaps the finest ridge of all, Great End to Sca Fell. Alongside on the east lie the upper Esk valley and the Bow Fell–Crinkle Crags ridge. The latter has wild rocky exposures and much evidence of ice action without any trace of the subdued relief. This brings us round to Langdale Pikes and our circuit is complete. Nowhere did the Lakeland ice cap have an unimpeded flow outwards except to the south and south-east. On the west it was blocked by the Irish Sea ice on the north by the Scottish, on the east by the Scottish and Eden Valley ice.

The three features of the summit land on which any interpretation of its history must depend are: the shape of the surface, the presence or absence of erratics, and the development of a considerable amount of absolutely local drift even if this is more or less patchy.

The characteristics of this summit land seem to indicate that first, a complete ice-cap lay all over the central area with ice so deep that its movements were capable of modifying the rock surface almost everywhere. A small fraction of the surface was left substantially in its preglacial condition and these fragments lying to the east mainly give an indication of a thinning out of the ice on the summit land in that direction.

Secondly, there was a great glacier to the north-east in the Ullswater drainage area communicating with the ice-cap on the south and south-west but somewhat isolated by the Helvellyn Dods and Hart Side on the west and by High Street on the east.

And thirdly, the Hawes Water glacier was separated from the Ullswater area by the range of High Street with its upper end surrounded by the subdued summit land of High Street, Harter Fell, and Dr. Mitchell's Mosedale area, but linked up through the Nan Bield Pass with ice flowing south.

Distribution of the subdued land

From the preceding paragraphs it is evident that the highest subdued summit land is situated mainly towards the eastern part of the area. The most westerly big portion is the western slope of the Helvellyn range followed towards the north by the Dods and having on its eastern side the considerable area of Hart Side. Most of this land lies at an elevation of 2500–3100 feet. Stony Cove Pike is a small area at 2500 feet (Plate 11). The next area lies on High Street. Beginning at the south end of this range there is a patch around Yoke at 2000 feet and upwards. On High Street proper the elevation may be put at 2000 feet–2700 feet followed farther north by High Raise at 2000–2500 feet. The later heights are taken from Dr. Mitchell's paper already mentioned. His eastern patch in the Mosedale area lies from little above 1250–2000 feet. The Howgill summit area described by Marr and Fearnsides lies farther east still. These details show that the subdued land of the Lake District lies towards the eastern side and the elevations show a decrease in height as one travels towards the eastern border. Coupled with the fact that all the ridges and most of the tops farther to the west consist of the rugged land, this suggests that the precipitation causing the glaciation was heaviest in the west and that it came from that direction. This tallies with what Mr. A. Farrington found in the Wicklow Mountains. To-day the maximum rain-

9. Sheffield Pike with erratic dropped by Ullswater glacier

10. Grisedale moraines in U-shaped valley, Place Fell in distance

11. Head of Ullswater with smooth Stony Cove Pike left distance and rugged Arnison Crags in centre

12. Langdale Pikes and Blea Tarn

13. Looking along Striding Edge to Helvellyn

fall is over 150 inches for the region about Seathwaite, but drops to 100 inches in the Helvellyn and High Street districts.

Development of the subdued land

Reference has already been made in a preceding paper in the *Journal* for October 1942 to the processes which have generally been thought responsible for the development of those rounded areas. Normal weathering seems to produce this subdued land mainly where the products of disintegration remain in situ to cloak the weathering rock. In another paper it was pointed out that above 2400 feet these areas are at present subject to solifluction movements evident in many surface phenomena. This has the result of preserving and continuing the rounding and subduing influence. It is noticeable that these solifluction results are less in evidence towards the western more maritime part of our area than they are in the more easterly portions. This emphasizes the divergence between the two tendencies, first, the greater precipitation in the west tending during cold periods to greater glacial action, and secondly, the more continental condition of the eastern areas tending to a later continuance of severe frost action. As these are solely summit observations they need not be regarded as contradictory to what other observers may have recorded of the direction of ice retreat at low levels. It is the high land that caused the great precipitation. While that precipitation during the cold periods took the form of snow the result was the continuous solid ice-cap all over the western higher parts that created such a continuous area of rugged land. When in the milder periods the precipitation was in the form of rain the result was that the disappearance of the ice was speeded up in these same western parts. Thus in the western half the heavy precipitation may have caused the intense glaciation while in the eastern half the higher portions, though less heavily affected, may have preserved the valley ice longer.

The following conclusions emerge from this study:

The result of ice action depends greatly on the nature of the rock. A heterogeneous rock or one possessing widely-spaced big joints gives rise to a rugged landscape while a homogeneous rock with small closely-spaced divisional planes gives rise to much more regular outlines.

Dr. Marr's interpretation of the subdued summit land as a relic of the preglacial surface is supported by an examination of the erratics on the high-lying tracts.

There seems to have been a continuous ice-cap over the central and western parts of the area with a thinning out of the ice on the more easterly elevated ridges.

An Ullswater glacier can be recognized as separated in parts from the ice-cap but still joining it on the south and south-west.

This may well be the last Lakeland study that the writer attempts. I should therefore like to express my gratitude to Mr. Burdus Redford for the photographs of Borrowdale and Skiddaw, to Dr. G. H. Mitchell for permission to use the results of his work in the eastern parts of the district, to Dr. S. E. Hollingworth for many most helpful conversations, and above all to the memory of Professor Marr, whose kindly encouragement first led me to such a delightful pastime.

THE LESINA PORTOLAN CHART OF THE CASPIAN SEA

E. P. GOLDSCHMIDT

IN 1913 I had as a keen student of early printed books joined the enterprise of the General Catalogue of Incunabula which was then being initiated by Professor Konrad Haebler. The plan was to register all known books printed before 1500, and the scheme was conceived on an international scale, most European governments having promised their collaboration. The work was well under way in Germany and France, and the Austrian government, having formed its own commission for the purpose, undertook to afford every facility for research in its libraries. Having close family connections in Austria, I was anxious to volunteer for this interesting task and, on Haebler's proposal, I was accepted as an assistant for this purpose.

That is how I came to set out on a journey through Dalmatia during the months of March, April, and May 1914, in the course of which I visited forty-nine libraries in that beautiful country, then a province of the Austrian Empire. Most of these libraries were in Franciscan convents, generally ancient and very poor foundations. Their books were few but often quite interesting, because they had mostly stood on their shelves for centuries. Accessions after 1600 were exceptional. The harvest of otherwise unknown incunabula, which I had hoped for, was meagre and would hardly have justified three months' travelling. But apart from the enjoyable and instructive experience of getting acquainted with a picturesque and interesting country I achieved some results, though of the finds I made only a few were of strictly bibliographical interest and one of the best was entirely outside my province.

Among the Franciscan convents I visited was that on the island called Lesina in Italian, Hvar in Croat. An ancient little house with a neglected, dusty, and thoroughly unimportant library. They had a few hundred volumes, all fairly old, and no catalogue. When I had finished looking through their books, I had registered thirty-six incunabula, all rather commonplace theological works printed in Venice. But among their folios I found a fairly good copy of the Strassburg, 1525, Ptolemy atlas. Looking through it I found on the fly leaves at the end of the volume a double-page hand-painted map, or rather a navigation chart on paper with the rhumb lines crossing a blue sea and some attractive looking towns with towers and cupolas painted red and yellow behind the coasts. The land was greenish, and some of the islands bright scarlet. The size of the chart, including margins, but not the scale at the foot, was approximately $43 \times 29{\cdot}5$ cms.

For a long time I could not make out what sea it represented. There were plenty of place-names along the coasts, and the writing was clear enough: Odatubissi, Charutebassi, Allamoy, Chiseliha, and so forth. Not a single name could I find that sounded familiar. The writer was using the Italian language. There was a Monte de Codeman, a Montagna de Balcan, a Cavo e Monte de Ursach, a Porta de Ferro. He also knew Latin; for here was the Monte de Marochos hic est serpens magnus. But where were all these places? At last I found in one corner, quite inconspicuous and rather faint, the legend "Mare de bachu." That gave me the clue: it was the Caspian Sea.

It struck me that a chart of the Caspian, dating from about 1525, might be of interest. I had my camera with me and, for the purpose of taking exact type-photographs when required, a special attachment by which I could take very precise photographs in natural size. So I took one picture of the entire chart and three of portions of it in exact full size.

I am glad I did this, for it would be difficult to discover where this map is now. When I returned to Spalato (Split), I reported on the results of my tour to Monsignor F. Bulic, the great archaeologist and excavator of Salona, who was in charge of the historical monuments of Dalmatia with the title Landeskonservator. I proudly told him of this map and I gave him prints of my photographs. Some time later he informed me that the map, which I myself had detached from the broken binding where it was in danger of being torn in half, had been handed to him by the librarian of the convent and that it was being preserved in some museum or library in Spalato. That was in 1914.

From Dalmatia I went back to Vienna, the headquarters of the Austrian Incunabula Commission, to work out and deposit my report, and there I had my Caspian map negatives enlarged to full natural size and several prints taken. With one of these I called on Professor E. Oberhummer, who was then Professor of Geography in the University of Vienna. He pronounced my find to be very interesting and suggested it should be examined by a specialist and, with my ready consent, he forwarded my photograph to a professor in the University of Kazan. A few weeks later the 1914–18 war broke out.

This account of when, where, and how I found this map constitutes all the information I can give with authority. If I venture to make a few further remarks on some points that strike me as interesting I wish it to be understood that I have no special knowledge of the subject.

My reasons for taking the date of the chart to be earlier than 1525 are the following. It was bound into, not pasted in but stitched in, a copy of the 1525 Ptolemy which itself was in its first contemporary binding. This binding was certainly of Adriatic workmanship, similar to hundreds I had seen in Dalmatian libraries, that is, a type of which the models would be Venetian, but which was obviously being followed in numerous binderies in various towns on the east coast. Whether this binding was made at Ragusa (Dubrovnik), at Spalato (Split), at Sibenico (Šibenik), or possibly in Lesina (Hvar) itself I do not think anybody could say with certainty. The binding was not much later than the date of the book and the volume had no doubt stood undisturbed in the convent library ever since some early owner gave it to the brethren as a gift.

The prima facie probability that a map bound with a 1525 book within a few years of the date of printing would be of the period 1500–25, if not earlier, accords well with the general appearance of this chart and with the character of the script of the legends.

About the author of this portolan we cannot draw many inferences, but he may well have been a Dalmatian. The language he uses in his legends accords entirely with such a surmise, and I think we can assert that his spelling, his system of representing Tatar words phonetically in writing, corresponds to the conventions of the Venetian dialect, which would be the natural orthography

for a Dalmatian. In Venetian spelling x would stand for our consonant "sh," ch for k. When our pilot wrote Chexech I believe he meant us to pronounce it Keshek.

That Dalmatian seamen were among the most enterprising navigators in the Mediterranean and beyond is well known; also that many of the most formidable pirates had their homes in this region. The captains and merchantmen of Ragusa, of Traú, of Sibenico, and of many of the islands sailed to Marseille and to Spain as well as to the Levant, the Bosporus, and the Black Sea. The deep fjord of the Bocche di Cattaro remained a most redoubted pirates' nest till well into the seventeenth century, and the magnificent empty stone palaces of the little town of Perasto still testify to their prosperity. It would hardly be surprising if one of these seafaring Dalmatians had earned his living by sailing the Caspian Sea in the early sixteenth century.

On the history of navigation in the Caspian my amateur researches have not brought me much information. There must always have been some traffic between the Persian ports, the Caucasus, and the Volga. G. de Rubruquis has a brief chapter on the Caspian Sea which he skirted but did not cross in the thirteenth century. W. Heyd, in his 'Histoire du Commerce du Levant' (1885–86), II, p. 232, tells us that about 1340–50 a crossing of the Caspian Sea was not considered an unusual event. Still I believe this portolan, by proving that navigation on that land-locked sea was not solely carried on by natives, but that Italian-speaking professionally-trained pilots had a share in it in the sixteenth century, brings us a little fresh information.

Note on origins and identifications

A comparison of the outline of the Caspian on this chart with modern maps will show that it gives a remarkably good representation. The general proportions are fairly correct, though the length is somewhat exaggerated in relation to the width. Particularly striking for the period is the representation of the east coast, with its indication of peninsulas and gulfs. The Apsheron peninsula on the west coast however is not very conspicuous, though that part of the chart is rather obscure. The chief departure from accuracy is in the coastline east of the Volga and in the contraction of the north-easterly gulf. This part was dangerous to navigate, as the chart indicates, and was not crossed by any important sea route.

The orientation, as indicated by the simple compass rose, shows that the major axis is tilted about 45° to the west, but since these are probably magnetic bearings, the error may not be so much as this. As is noted in more detail below, the coastal names are numerous and many of them are close renderings of local forms. In all these respects, proportion, outline, and orientation, this chart is much superior to contemporary maps, and also to those of a much later date. There is however a collection of charts of Venetian origin, assigned to *c.* 1489, in the British Museum, which contains an anonymous chart of the Caspian. From the brief indications given by Uzielli and others, it is possible that this resembles the chart under discussion. Unfortunately, it has not been possible to examine it, or to obtain a photograph for comparison. The normal portolan chart did not include the Caspian. For its early delineation there are two main types. The most general was based upon Ptolemy, and represented the sea approximately as an ellipse with the longer axis running east and west. This type persisted at least until the end of the sixteenth century, and was used for example by Battista Agnese. The second type appears in the fourteenth

The Lesina chart of the Caspian Sea: approximately two-fifths of original size

The northern and north-western coasts of the Caspian, including the Mangishlak peninsula and the Volga delta

century. The orientation is rather better, and there is some attempt to represent prominent features of the coast-line. The Medici Sea Atlas of 1351 and the Catalan chart of 1375 are examples of this type. This improvement was perhaps due to information from Genoese sources. In the fifteenth century a considerable advance was made. Mr. Goldschmidt shows that this Lesina chart cannot be later than *c.* 1525. It, or its prototype, if it is a copy, may well date from the fifteenth century. It is probable that charts of this type were in circulation by the middle of this century, for the outline of the Caspian on Fra Mauro's map, 1459, has a considerable resemblance to this, but very few names along the coast. This more accurate representation however was not generally adopted, and not until the Russian surveys of the eighteenth century was the standard of this Lesina chart surpassed.

The source of the knowledge upon which this chart was based is clear. The first relatively correct idea of the Caspian resulted from the journeys of the thirteenth century missionary friars. Carpini on his way eastwards crossed the Volga near Sara, above the delta: Andrew of Longjumeau on a mission to the Mongol court skirted the southern and eastern shores of the Caspian, and Rubruquis on his return travelled down the Volga to Sara and then skirted the north-western shores to beyond Derbend. These journeys caused one classical idea of the Caspian as an arm of the northern ocean to be abandoned, but detailed knowledge of its coasts was due to the commercial enterprise of Genoese and Venetian traders. They had penetrated into the lands around the Black Sea and the western Caspian by the thirteenth century and were trading with the Tatars. From the fifteenth century there are narratives of Venetian emissaries to the Persian court. Those of Contarini and Barbaro especially contain much information on the trade and routes of the regions west and south of the Caspian. According to Marco Polo, the Genoese were building their own vessels for the navigation of that sea at the beginning of the fourteenth century. The extent of their operations is obscure, and there seems to be no evidence that the Venetians acted similarly: in the fifteenth century they were using local vessels. However as this chart testifies they accumulated much detailed information which was not superseded for several centuries as far as western Europe was concerned. It may be added that in 1558 Anthony Jenkinson voyaged from Astrakhan to the Mangishlak peninsula on his way to Bokhara.

Perhaps the most striking feature of this chart is the large number of names, almost all confined to towns or features along the coast. They are much more numerous than those on other contemporary maps, of which the Catalan map has the next greatest number. It is noteworthy that apart from the names of the more important features and towns there is little correspondence between the two sets of names. On the Lesina chart there are many in the form "cauo e moñte de . . .," or "ponte de . . .," and this supports the suggestion that the chart was actually drawn by and for navigators.

The identification of the names presents considerable difficulties. The whole region lay on the borderland between the old world and the Asiatic steppes, and was overrun by successive hordes of invaders, the most ferocious being the thirteenth-century Mongols. Thus Persian, Turkish, and Tatar names are intermingled, and the later Russian advance has led to a further change in the nomenclature of large areas. It is possible that some of the unidentified names are derived from those of earlier settlers. Finally, the forms in which they appear on the chart are the attempts at representing unfamiliar words by a medieval cartographer, who, if he were a copyist, may have introduced additional errors. In the following notes, the names are dealt with in the order north, west, south, and east.

Conspicuous in the north-west corner is the lower course and delta of the Volga. The name given to this river is illegible on the photograph, but appears to be "Atel" or "Itil," the medieval name said to represent the Tartar river. The name Volga appears for the first time in west European literature in the narrative of Carpini. Rather faintly, and at a little distance to the west of the river is "Gittarcan," a rendering of the Tatar Haji-tarkhan, the name of the old city of Astrakhan. "Tarkhan" is said to have been the title of minor Tatar kings. Astrakhan was destroyed by Timur in 1395, and a new city built later a little distance downstream. Opposite Gittarcan is "Saray" or Sara, the capital of the Kapchik Khans, also destroyed by Timur. The name means palace, having the same root as seraglio. The city was an important crossing place on the Volga, visited by many medieval travellers, and was sufficiently well known to supply one of the names of the Caspian (Mar de Sarai).

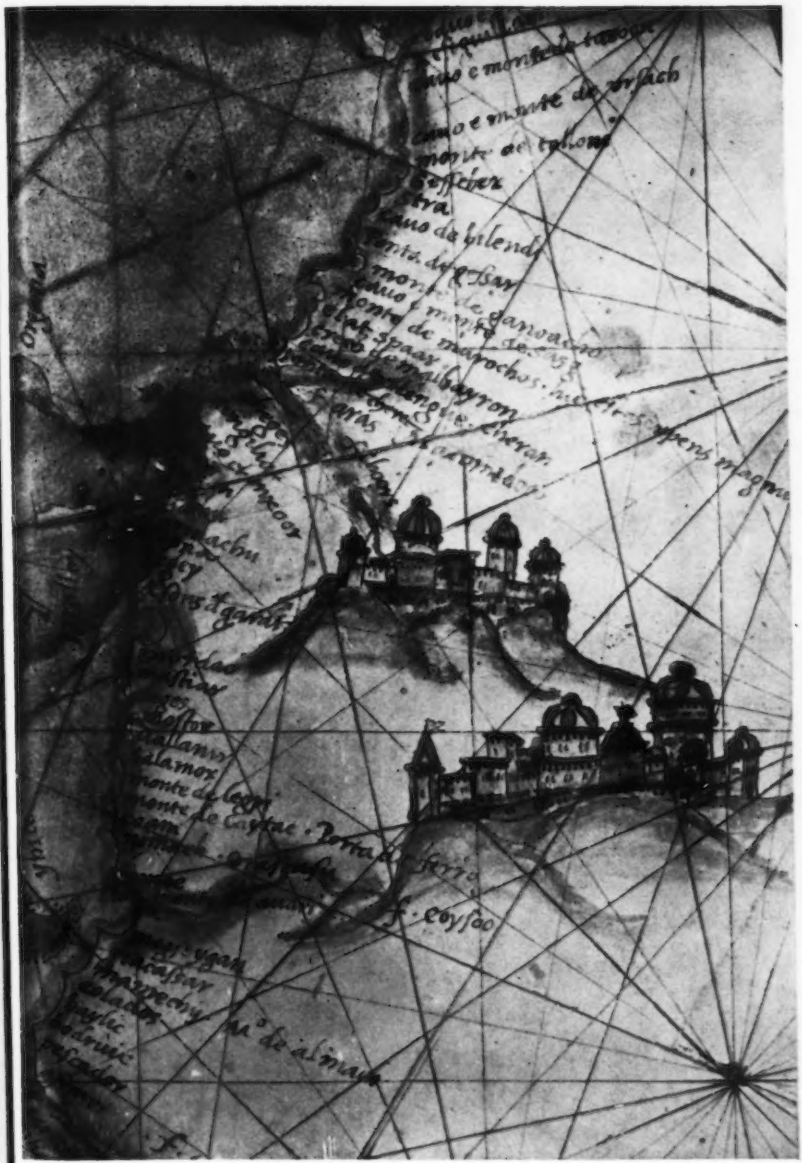
East of the delta is "Iangoquent," which is a rendering of the Turkish Yanghi Kant, or New town. It is possible therefore that this is intended to represent the new city of Astrakhan. If this is so, it is evidence that the chart is later than the fourteenth century. There is however another possibility. According to Le Strange, there was a town of this name near the entry of the Syr Daria into the Aral Sea. The similarity in the position of the two places and a confusion between the Aral and the Caspian may have led to the transposition of Iangoquent. The first hypothesis seems to be the more likely.

To the east is the "F.Yayto," the Ural river, the Tatar name for which was Yaik. The eastern route crossed this at Seraichik, and this may be represented by the "Sarayoce" of the chart, though it is at some distance from the river.

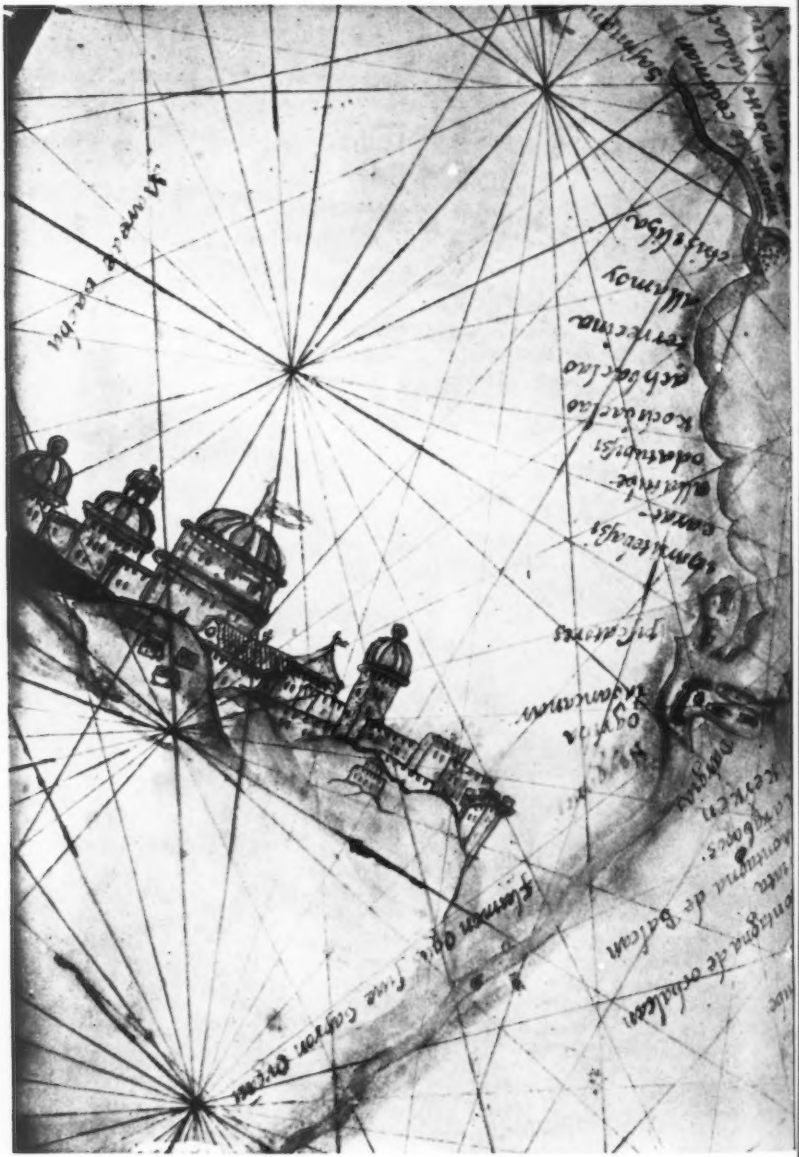
On the western coast the names are very numerous. The most conspicuous features are the four rivers, of which the lower courses only are shown. On the north is "F.terchy," the Terek. To the south is a river, "Orastasu," the upper portion of which is named "f.coysoo." The latter may be an attempt at showing the various tributaries, the modern Andiskoe Koisu, Avarskoe Koisu, etc., which come together to form the Sulak. The "f.choors" is the Kur or Kura, and the "f.aras" which joins it shortly before it enters the sea, is the Araks or Aras.

Between the Volga delta and the Terek there are a surprising number of names, considering the barren nature of the coast. Several of these have the element "tube," which may be allied to the Turkish "tepe," a hillock, applied to the numerous sand ridges which are a feature of the littoral. The first term in "casar dercoci pescador" suggests the Arabic "Kasr," a term with a wide range, here seemingly applied to a fishing settlement. The only one of these names for which an approximate location can be suggested is "Iarlach." In Pallas' 'Second voyage' (Paris, 1811, vol. I, p. 358), he refers to a great lake south of the mouth of the Kuma, a western arm of which he calls Jarlatschi. He gives no explanation of this name, though he does for many others.

It seems strange that among the towns on this coast-line Derbend does not appear, though it is found on earlier charts. However near the Koisu appears the inscription "Porta de ferro" and a drawing of a large city. This is probably intended to represent Derbend for the phrase is a literal translation of the Turkish name, Demir kapi, of that city. It owed its name of the Iron Gate to the fortifications which extended across the narrow plain and into the mountains, and barred the inroads of the nomads from the north. Tradition associated them with Alexander the Great. North of the Kura is "Barmachu," identified by Bagrov with Besh Barmak, a conspicuous mountain near the coast to the north of the Apsheron peninsula. The name is said to be Turkish, the five fingers, in reference to the outline of the summit. This mountain was



Part of the west coast of the Caspian from the Terek to the neighbourhood of Resht



Part of the eastern coast of the Caspian, with the former arm of the Oxus

evidently an important sailing mark, and is mentioned by Venetian and English voyagers on the Caspian. The names immediately to the south are difficult to decipher, but it is possible to make out ". . achu," probably Bachu (Baku) derived from the Persian Bakuh or Bakuyah. The large city drawing no doubt emphasizes the position of the most important port on the Caspian or Mar de Bachu. This is an interesting example of the persistence of a name despite historical changes, for the city changed hands between Persians and Turks before its annexation by Russia. Off the Apsheron peninsula there is an island with the name "piralloy." This name continued in use for a considerable time, appearing in the form Piralagoi on nineteenth-century maps. The island is now known as Svyatoi. Below Baku, "Stra" is probably the small port of Astara, a name also of Persian origin.

On the south coast, where Persian influence has been uninterrupted, several of the names have remained practically unaltered, *e.g.* "Amol" the modern Amul, the capital of Tabaristan ravaged by Timur at the end of the fourteenth century, and Sari, an earlier capital. "Alam," to the west of Amul, was the port of that city, Ain al Humm, written as Ahlum by Yakut.

In the south-east corner, a little way from the coast, is "Straua," a common form of Astarabad (Starabad) in the narratives of early travellers. The "u" should perhaps be read as "v," interchangeable with "b," giving Straba. The city was an important centre of the silk trade, and the fabric obtained thence was known to the Venetians as stravatine.

One would expect to find in the south-west corner the city of Resht indicated. In approximately the correct position appears "Resiquillam," and it is suggested that this stands for Resht i Gilan, Gilan being the province of which it was the capital. I have not been able to find any clue to the curious name "ihalegrostandex" near by.

In the south is a drawing of a city with the name "Corazan" close by, *i.e.* Khurasan. This may stand either for the province or for its capital city; the latter at this period was Nīshāpūr, on the great trade routes to Bokhara and Herat.

On the east coast Turkish or Tatar influence is in evidence. The large peninsula in the north is represented with the name "Machislac" written rather faintly. This is evidently the Poluostrov Mangishlak of modern Russian maps. It was on this peninsula that Anthony Jenkinson landed in 1558. The name is said to be compounded of the Turkish words Mangu and kishlak, *i.e.* winter settlement of the Mangut Tatars. The most interesting feature is the large river entering the sea rather more than half-way down the coast, and bearing the inscription "flumen Ogus siue Gayron Orgāci." This is the arm of the Oxus, now known as the Uzboi, by which that river discharged into the Caspian between the early thirteenth and sixteenth centuries (see Le Strange, pp. 455–8). "Orgāci" is a contraction of Organci, a city known to the Arab geographers as Al-Jurjaniyah, and later as Urganj, the Urgence of Jenkinson's narrative. It lay south of the sea of Aral and to the west of the present course of the Oxus. The river enters the sea south of a "Montagna de Balcan," just as on modern maps the Uzboi is shown to the south of the Great Balkhan. Close by to the north is "Karabogos," a name which is still preserved in that of the Karaburgas Gulf, though the name does not appear near any very large gulf on the chart. Another indication of Tatar influence is the name "Alatao" given to one of the two islands off the mouth of the river, for Atau is the Tatar for island.

It is evident from the place-names and the configuration of the coast-line that this portion of the chart was compiled from actual knowledge. The representation of a considerable river debouching there into the Caspian may therefore be taken as supporting the contention that during medieval times the

Oxus resumed for a period its course to the Caspian. This has been often disputed, though there is evidence from later Arab geographers to support it, and Jenkinson noted at the time of his visit that though the Oxus was then again flowing into the Aral it had formerly discharged into the Caspian. Other more or less contemporary charts also show this course, but without the convincing detail of the Lesina chart, so that they may merely be perpetuating the classical tradition.

In identifying these names I have used a number of works. L. S. Bagrov, in 1912, published a historical sketch of Caspian cartography (Materialij k istoricheskomu obzoru kart Kaspiyskago Morya), which contained useful reproductions, but he does not seem to have known of a chart of this type. For Arabic and Persian names I have used G. Le Strange's 'Lands of the eastern Caliphate,' 1930 edition, and V. Minorsky's edition of the 'Hudūd al-'Ālam,' 1937. Much information has also been obtained from the narratives of early travellers in this region published by the Hakluyt Society. G. R. CRONE.

HYDROLOGY

HYDROLOGY (Physics of the Earth, vol. 9). Edited by OSCAR E. MEINZER. *London: McGraw-Hill*, 1942. 10×7 *inches;* xii+712 *pages; illustrations and diagrams.* 52*s* 6*d*

THE physics of the earth, Geophysics, is the connecting link between physics and geology and deals with the physical methods of our planet. It embraces Meteorology, Oceanography, Terrestial Magnetism, and Hydrology. The last-named, in its broadest aspect, is the study of the circulation of water from ocean to atmosphere and its return as precipitation to ocean, either direct or overland—the so-called hydrological cycle; but it is the latter phase with which it is particularly concerned.

Hydrology can be divided into four main sections: potamology, the study of surface streams; limnology, the study of lakes; geohydrology, the study of subterranean waters; and glaciology, the study of snow and glaciers. Hydrology is by no means a new science, but much of its terminology is of recent date and some of it is neither very good nor very necessary. For example, the International Association, under whose aegis hydrology as we know it to-day has been built up, calls its field Scientific Hydrology in order to distinguish it from applied hydrology; yet the work of the Association includes such subjects as the forecasting of run-off for irrigation and the storage of flood waters by dams, both examples of applied hydrology. There can in fact be no firm dividing line between the two and the distinction is therefore artificial and unnecessary.

Another example of unfortunate terminology is that advocated in the work under review for the science of snow and ice, "cryology." Cryology literally means the science of cold. The far more accurate "glaciology" has been in constant and satisfactory use for a very long time, and both the reviewers feel very strongly that the word cryology is an unwelcome innovation.

'Hydrology' is the last of a series of nine "related monographs" on the physics of the earth. There are fifteen chapters, each contributed by one or more authorities, and the whole is edited by Mr. O. E. Meinzer of the U.S. Geological Survey. It is well printed and illustrated, with a moderately good

index and a bibliography at the end of each chapter—the proper place for a bibliography. The bibliographies vary in excellence however, some concentrating upon American literature at the expense of work done in other parts of the world. The work is timely in that it provides a wide-ranging treatise on the science in the English language and at the same time is much more up to date than Gutenberg's 'Handbuch der Geophysik,' hitherto the standard authority. And yet there may be people who will prefer the more concise and systematic arrangement of the older work, for the multiplicity of authors in the present book has caused a certain lack of uniformity which has not yielded to capable editing. There is too much detail in some things and too little in others. Nevertheless the volume should have a wide appeal, both here and in the Western Hemisphere, because of the increasing demand for more scientific knowledge of problems relating to water-power, irrigation, ground water, flood control, and conservation of forests and soil, and should provide an excellent reference book for scientists, engineers, and advanced students.

The chapter arrangement more or less follows the accepted sequence of the hydrological cycle except that the chapters on evaporation do not come at the end as might be expected from the fact that the opening chapter of the cycle deals with precipitation.

Chapter I is an introduction by the Editor. It describes the general conceptions of the science and concludes with an interesting history of the development of hydrology from ancient times to the present day.

Chapter II on precipitation by Merrill Bernard could profitably have contained more detail. Mr. Bernard's energy and ability have been largely responsible for the advances made by the U.S. Weather Bureau in recent years, such as the installation of increasing numbers of recording rain gauges on important watersheds in areas inaccessible to the daily observer, many of these reporting periodically by wire or radio. Another important project which Bernard sponsored was the shielded snow-gauge developed by J. Cecil Alter, mentioned in Chapter IV. This equipment has been installed in large numbers throughout the U.S.A., and a few, cooperatively, in Canada, and has proved most useful in rationalizing records of snowfall.

Chapter III on evaporation from free water surfaces by Sidney T. Harding is complete and up to date. It is a pity though that in a passing reference to evaporation from ice and snow he suggests that little is known about it. There are in fact quite considerable data available.

Chapter IV, "Snow and snow surveying; ice," by Dr. James E. Church, covers in considerable detail the measurement of snow and its water content and its relation to run-off as developed at present in forecasting. The chapter contains a wealth of valuable information. It must be admitted however that the development of snow surveying has been largely empirical. Sóme broad underlying fundamentals certainly appear to exist, but there are many major and minor factors which affect the relationship between the water content of snow and run-off. Two known major factors are precipitation during the run-off, and the moisture content of the soil beneath the snow blanket, and either of these factors can in some regions render forecasting unreliable, though allowance can sometimes be made for them. In practical forecasting the so-called minor factors can generally be ignored; to some extent they evidently tend to cancel out. The term "minor factor" must therefore be accepted with reservations as it is conceivable that quite major ones are compensated for as well, and it is therefore only the total which is minor. In the experience of one of the reviewers (R.C.F.) cases have occurred of unexpected differences between forecast and actual run-off, which were certainly caused by unsuspected factors.

In ignoring these unknown factors as long as they only cause minor discrepancies the impression may be given that their existence is denied, which probably accounts for the reservations with which the scientific mind sometimes accepts snow surveying.

The many influences which affect the relationship between snow water content and run-off are now being studied. The Committee on Snow of the Section of Hydrology of the American Geophysical Union has a permanent research sub-committee at work; at the moment the physics of snow melting and the maximum melting rate are under investigation. With the cooperation of a number of laboratories and educational institutions, determinations are being made of the thermal quality of snow and its effect on the rate of melting and thence run-off. Other research projects are: the capacity of new and old snow of various depths and densities to absorb rain and the effect of rain temperature on the rate of melting. Evaporation during the run-off period may have a large effect on the water content/run-off relationship, particularly in semi-arid regions. One of the reviewers (R. C. F.) suggested this as a research project just before the war, but has no knowledge of it having been undertaken.

It therefore seems a pity that Dr. Church makes little or no mention of these distorting factors, or of the efforts being made and results so far obtained in identifying and studying them. As an example of the lack of uniformity mentioned above the snow densities in this chapter are expressed as percentages whereas in other chapters specific gravities are given as in most glaciological and in all other scientific treatises.

Chapter V, by F. E. Matthes, is an able essay on glaciers. While perhaps not so systematically arranged or so full of detail as Hess' excellent work in the 'Handbuch der Geophysik,' it starts with the great advantage that recent discoveries have made definite much that was largely theoretical or hypothetical in Hess' work. The omission of detailed descriptions of crevasses, moraines, glacier temperatures, glacier bands, and subglacial streams is the more disappointing because of the excellence of those themes which Mr. Matthes does handle. Almost for the first time since Emden's day much space is devoted to the transformation of snow into glacier ice, while the nature of glacier flow is dealt with in great detail and with clarity. On both these subjects Mr. Matthes bases his conclusions upon work done by the British Jungfraujoch Research Party of 1938 whose results have since been confirmed in the United States by the late Dr. M. Demorest.

Mr. Matthes accepts these results as having finally settled the century-old controversy on glacier flow. He agrees with the Jungfraujoch conclusions, obtained by field observation, that both plastic deformation of the crystals and shearing motion of one ice mass over another are to be found. Demorest took the Jungfraujoch work a stage farther by suggesting the conditions under which each of these factors operates, but observational proof seems necessary before his thesis can be considered fully proven. Mr. Matthes accepts, perhaps a little too easily, the theory originally hinted at by von Drygalski and by H. F. Reid and recently put forward by Streiff-Becker that in certain parts of their courses glaciers flow faster near their beds than at the surface. Some years ago one of the reviewers (G. S.) gave some credence to this theory, but here too observational proof is necessary before it can be accepted.

The last part of the Chapter is an excellently argued section on the variations of glaciers since Pleistocene times. Mr. Matthes adheres to the view that for the last three hundred years there has been a general trend of glacier increase all over the world following a post-Pleistocene period of greater warmth than at present. The retrogression of glaciers which began in the middle of the last

century is, so far as it has progressed to date, a minor fluctuation in the opposite direction to the general trend.

Chapter VI on lakes is also by S. T. Harding. He gives a clear and concise description of types of lakes based on their origin; the causes of lake surface fluctuations; effects of temperature; effects of silt and other matter carried either in solution or suspension. Numerous examples of lakes of various types are given; all are in the U.S.A.

Chapter VII on infiltration is the joint contribution of Leroy K. Sherman and George W. Musgrave. Both are well known for their diligent research and contributions both to hydrology and hydraulics. The chapter is brief and here again perhaps more detail could have been given, although a wealth of information is compressed within the compass of a few pages.

Chapter VIII on transpiration and total evaporation is by Charles H. Lee. The subject is covered in considerable detail and contains some very valuable compilations, both in tabular and graphical form, of transpiration ratios for a wide variety of plants, field crops, shrubs, and trees, and also of consumptive use of water in widely scattered regions under different conditions of climate and vegetal cover.

Chapters IX and X are on soil moisture and ground water respectively. Chapter IX deals with capillary action, Chapter X with the broader aspects of ground water hydrology. As the phenomena of the capillary zone form part of ground water hydrology it might have been better to include them in one chapter under Ground Water Hydrology or else to have reversed the order of the two chapters. The subject of ground water is one of the most complex in hydrology, involving physics, chemistry, and geology. Although much research has been done there are still many unsolved problems. The authors of these chapters have given a masterly discussion of their subjects and the bibliographies are among the best in the volume.

Chapter XI, on run-off, is divided into nine sections by seven different authors. It gives an excellent outline of the development and present status of the approach to run-off problems; it is mainly practical and factual, and is surprisingly brief considering the scope of the subject.

Chapter XII, on droughts, by William G. Hoyt, gives a useful discussion of these phenomena, which may be regarded as a special case of precipitation, its abnormal lack, but he deals with droughts in the U.S.A. only.

Chapter XIII is another chapter of composite authorship. Its five sections are by as many authors, who deal with various aspects of physical changes produced by the water of the Earth. Much of the chapter covers specialized aspects of subjects discussed in previous chapters; there is therefore a certain amount of inevitable repetition. Broadly, it covers in considerable detail the twin phenomena of erosion and sedimentation. The segregation of the subject-matter into a separate chapter is no doubt felt to be justified in American eyes because the subject of erosion has become a problem of national importance.

The last two chapters, XIV and XV, on the hydrology of limestone terraces, by Allyn C. Swinnerton, and the hydrology of volcanic terraces, by Harold T. Stearns, respectively, are special cases of ground water hydrology, and for the sake of continuity might better have followed Chapter X. These chapters contain more detail than is general in the book, and on this score their inclusion hardly seems justified, despite the fact that the subject-matter is important.

GERALD SELIGMAN.
R. C. FARROW.

REVIEWS

EUROPE

IRON AND STEEL IN BRITAIN, 1870–1930. By T. H. BURNHAM and G. O. HOSKINS. *London: George Allen and Unwin*, 1943. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches; 352 pages; diagrams.* 25*s*

It is common knowledge that most of the fundamental inventions in the iron and steel industry were born in Britain; well known too that Britain was geographically favoured by the abundance of coal and iron ore in close proximity. Yet whereas in 1870 Britain produced 50 per cent. of the world's pig iron and 43 per cent. of the world's steel, by 1930 our share had dropped to 8 per cent. of each. And whereas in 1870 Britain's exports of iron and steel amounted to some four-fifths of the total exports of the five leading producing nations, by 1930 our share had dropped to one-fifth and, moreover, Britain was the world's chief importer of iron and steel.

It is the purpose of this book to examine the causes which limited the economic development of the British iron and steel industry between 1870, a date which marks the beginning of the "steel age," and 1930. A second volume is promised dealing with the events of the 'thirties, during which decade developments of a far-reaching character took place—developments which have undoubtedly contributed in very large measure to the efficient production of armaments during the last few years. The authors are well qualified for their task: one is an economist and the other an engineer with twenty-five years' experience in the iron and steel industry.

The causes of the relative, and in some directions absolute, decline of the industry are divisible into two classes: those which may be regarded as inevitable, such as the growth of competitive industries in the U.S.A. and in western Europe, and so beyond the control of British manufacturers; and those which may justly be regarded as avoidable, such as failure to make proper use of home ore resources, and obstinate clinging to out-of-date plant and methods.

In a sense the whole problem is geographical, or perhaps geological, in origin; though the geographer is so often prone to lay too much emphasis on the physical as opposed to the economic factors in industrial development, that it is as well not to stress this point unduly. The scattered distribution of our coalfields and orefields fostered the development of a multitude of small iron and steel industries, stimulated individualism, and militated against concentration and mass-production. Individualism was the very lifeblood of the industry in the early days, when Britain was supreme as a producer and exporter, but so soon as Germany and the United States, having at their disposal the huge orefields of Lorraine and Lake Superior, and the vast coalfields of the Ruhr and Pennsylvania, respectively, began to develop large-scale production, its advantages were for the most part nullified, and in fact it greatly hindered the progress of British industry. Individualism resulted in the existence of a large number of small and relatively inefficient plants for the manufacture of coke and the smelting of iron, and the inefficiency was increased by the British tradition of building equipment designed to last a long time. The youthful steel industry, which had such an early start in Britain, grew up to replace the wrought-iron industry, which itself had sprung up in a previous industrial age when coal for the forges and steam-hammers, and canal transport, were the chief localizing factors. The steel industry thus to a large extent inherited the geographical distribution of its predecessor, and the opportunity of securing the advantages of mass-production in large integrated works was lost. Small

producing plants had the advantage of diversity of output, but *laissez faire* and the open British market prevented that degree of integration and marketing organization which would have put British industry on equal terms with its European and American competitors.

The handicaps to the iron-smelting industry were numerous, but the chief was undoubtedly the serious lag in technical development; many of the furnaces were small and wasteful of heat and gases. High royalties on ore, and high railway rates, also contributed. Important too was the curious persistence in the manufacture of hematite and foundry iron despite our huge home resources of phosphoric ore of a character similar to that of Lorraine, which was contributing so largely to the growth of the basic iron and steel industries of France, Germany, Belgium, and Luxembourg. Persistence in the wrought-iron industry long after it had been almost abandoned abroad may also have been a weakening factor, for it entailed the survival of small blast furnaces for the production of forge pig iron, and developed a crop of re-rolling works which subsequently hindered the economic efficiency of the steel industry. Undoubtedly, too, wages were higher and production per man lower than on the Continent, especially after the 1914–18 war, and shipping rates on British lines were far higher than those charged by foreign lines from Continental ports to the same destinations. Competition with European and American producers was further hindered by the poor sales organization and by the multiplicity of merchants.

Other factors which contributed to the relative decline are concerned with the internal economic structure of the industry. Until 1913 it was an industry which made private family fortunes. "The sense of security from inherited wealth explains an inherent conservatism, and a marked tendency to retain aged directors led to a love of compromise, a hesitant development of policy and opposition to change except when driven" (p. 248). Further, the technical expert was seldom as important or as well remunerated as he who inherited the direction of commercial policy, and it is not surprising that science and industry did not advance hand in hand as they did abroad. After the 1914–18 war conditions had changed somewhat, but obsolescent plant caused the industry to be discredited as a field for capital investment, and the creation of new and up-to-date plants was rendered even more difficult by the depreciation of foreign currencies and our own return to the gold standard. The preference for high dividends rather than the accumulation of reserves for plant modernization had disastrous results.

There is thus no lack of adequate reasons to explain the position of the industry in the late 'twenties. Many other possible factors are systematically examined; some are rejected as being inconclusive or having no effect.

Were the lessons learned? The second volume will no doubt analyse the vital effects of the widespread scrapping and reconstruction policy which was formulated during the great depression. It is probable that in less than a decade the whole position was fundamentally changed, and the British industry put once more, technically if not economically, on a comparable footing with its chief competitors. It is as well for us that it was so; the story of how it was done will be most interesting reading; but, as the authors remark, Corby should have developed in 1900, not 1933. The iron and steel industry suffers in an acute degree from the problems of a capital goods industry, *i.e.* of adaptation to optimum market conditions and inability to withstand slumps. In 1921, after the 1914–18 war, obsolete plants went out of business by the dozen and never recovered. Perhaps this time there will not be quite so much obsolete plant.

The concentrated but always clear argument presented in this volume is supplemented by a wealth of statistical appendices covering, with their valuable

annotations, seventy-three pages. A large part of the statistical information has been collected from many foreign sources, and must have involved much calculation. For the non-technical reader there is a simple introduction to the main processes in the iron and steel industries, with definitions of the various types of products. The only serious misprints are a misspelling of the name Neilson (inventor of the hot blast) on pp. 22 and 38, and "million" for "hundred thousand" in the second table on p. 116. S. H. B.

ECONOMIC AND HISTORICAL GEOGRAPHY.

THE VOYAGE OF SIR HENRY MIDDLETON TO THE MOLUCCAS, 1604–1606. New and enlarged edition with introduction and notes by Sir WILLIAM FOSTER. (Hakluyt Soc. 2nd Series. Vol. 88.) *London:* 1944. $8\frac{1}{2} \times 6$ *inches;* xliv+210 *pages; frontispiece and maps*

In 1856 the Hakluyt Society published an anonymous account of the East India Company's second voyage of 1604, edited by Mr. Bolton Corney. The editor of the present volume, Sir William Foster, reprints this tract, 'The last East-Indian voyage' in the original text, the earlier editor having modernized it, and adds much valuable material. He has been able to clear up several obscure points, though the identity of the author remains unknown. The most important addition is the 'Exact discourse,' by Edmund Scott, the English agent at Banda, reprinted in full from one of the rare copies extant. Purchas published a fairly full summary of Scott and much briefer versions of the anonymous journal and the narrative of Thomas Claybourne, master's mate on the *Ascension*. Claybourne's manuscript appears to have been lost with Purchas' papers. The present volume contains therefore all the more relevant material now existing for a history of the voyage.

Sir Henry Middleton's success in reaching the Moluccas and returning with cargoes of nutmegs and cloves in addition to pepper came at an opportune moment in the history of the Company. The adventurers had earlier appeared rather hesitant as to its future, partly because the first voyage had resulted in a glut of pepper on the home market. However the combined results of the two voyages allowed dividends of 90 per cent. to be paid. Scott's narrative concerns his sojourn at Banda in Java between the first and second voyages, when his small party had a strenuous task in maintaining their position against native, Chinese, and Dutch interests. He describes these trials vigorously and very engagingly, and includes some interesting details about the Chinese trading community. G. R. C.

BIRUNI'S PICTURE OF THE WORLD. By A. ZEKI VALIDI TOGAN. Memoirs of the Archaeological Survey of India, No. 53. Government of India. *Delhi: Latifi Press,* 1941. $12\frac{1}{2} \times 9\frac{1}{2}$ *inches;* 162 *pages.* 12*s* 6*d*

Professor Togan, after many difficulties, has given us an edition of four extracts from treatises by the noted Perso-Arab geographer al-Biruni who lived during the first half of the eleventh century A.D. Some of these, published for the first time, will, he claims, provide a comprehensive survey of al-Biruni's geographical knowledge.

The first extract, from a work known as al-Qanun al-Mas'udi, consists mainly of tables of latitudes and longitudes of the various *iqlims* (or climatic zones) into which the Arabs divided the world, and the positions of the chief cities in each iqlim, all based largely on Ptolemy. Al-Biruni states that both Greeks and Indians were well versed in this science, but, the former possessing superior knowledge, he follows them. Professor Togan's footnotes make fre-

quent reference to other works of this kind which have been published of recent years by Nallino and Mžik. It must not however be thought that al-Biruni slavishly followed the Greeks, for he was a scientist capable of making his own observations, able to correct the errors of his predecessors, and to add to their sum of knowledge.

The second extract from 'The definition of the distances between places for the correction of distances between inhabited places' shows personal observation of an original nature unusual among medieval Arab geographers. For instance, though here on the authority of another writer, he reports that near Sirdjan in Kirman you find dead stumps of palm-roots in the ground although there are no longer living palm trees on account of the desiccation of the region. Again, he discourses on his theory that before the existence of mankind land had become sea and vice versa. The Arabian desert, he says, was once sea but the sea has become filled up; this can be perceived when wells are dug and there appear strata of sand, earth, small pebbles, then bones, pottery, and glass which could not possibly have been intentionally buried there. Stones are discovered which, split open, show evidences of fossilized shells and what is known to the Arabs as "fishes' ears." These are also to be found in the region to the south-east of the Caspian Sea. Al-Biruni notes that between the time of Ptolemy and his own era the course of the Oxus has changed, and he quotes frequently from Greek writers, occasionally even citing the Greek name for a Persian province, such as, for instance, Kirman. He speaks of finding astronomical tables (*zidj*) made in the time of Diocletian, at Ghazna, and tells how he observed an eclipse in Khwarizm (Khiva), comparing his findings with those of a brother savant who had observed the same eclipse at Baghdad. In this treatise, too, he repeats the well-known story of how the Caliph al-Ma'mun ordered a degree to be measured out on the earth's surface.

The third extract from the Kitab al-Djamahir fi Ma'rifat al-Djawahir, an important treatise on precious stones, minerals, and chemical substances known to the eleventh-century Orient, has already appeared in a complete edition of the work published by Professor F. Krenkow at Hyderabad in 1938. A translation of the latter edition is a desideratum.

The last treatise, on pharmacy (Saidana), is similar to the third. Each substance is considered under a separate heading, and a considerable body of miscellaneous information collected, from Greek, Arabic, Persian, Indian, and other sources, the equivalent names being given in a variety of languages, including the little-known Soghdian tongue, and some African words. Several varieties of drugs and spices were, it seems, commonly known as 'Omani, though they did not, of course, originate from there. The explanation is that they were landed at the ports of the 'Oman coast, and redistributed thence to Persia, Iraq, and the adjacent countries. One serious defect mars this interesting and valuable book. As is only too frequent with Indian publications, the proof-reading is very bad, both in the Arabic text and English preface. R. B. S.

THE MONTHLY RECORD

THE CZECHOSLOVAK–MAGYAR RELATIONSHIP

Dr. Clementis' monograph, "The Czechoslovak–Magyar Relationship," issued by *The Central European Observer* (No. 1, 1943, trans. R. Auty), is a short exposition of the cultural elements in these three groups, two Slav and one Finno–Ugric, and of the effects of juxtaposition upon their cultural development throughout the centuries. He discusses the traditional hostility between Slavs and Magyars in terms of academic literature, conditions of education, and the development of the intelligentsia. Of necessity, the main emphasis in the monograph is on Slovakia and on Slovak–Magyar relations. True, in the great crises of Slovak history, and especially in 1848 and 1918, the Czechs felt the Slovak cause to be their own, and for centuries the converse has also been true: the ups and downs of Czech development have been closely and sympathetically watched by the majority of Slovaks. But in the triangular relationship of Czechs, Slovaks, and Magyars, it is the smaller of the Slav groups which holds the key position.

No one can read this monograph without being impressed both by the deep-rooted enmity between the Slovaks and Magyars, and by its complications, whether the cultural, economic, or strategic aspect be uppermost. Apart from this antipathy of all Slovaks for all Magyars, which is returned with interest, there is the ill-feeling between the long-established and articulate Magyar aristocratic minority and the great Magyar peasant majority; and the fear and loathing of Slovaks and Magyars alike for the Germans, whom they encounter in two forms, as ancient minorities in their midst [1] and as a mighty and ruthless totalitarian group. The confusion of hatreds is alarming, although only too amply explained.

There is little direct mention in the monograph of the geographical setting of this unhappy struggle, but the all-important question of the control of the elementary schools brings the reader face to face with the everyday life of the peasant. It calls up a picture of hundreds of thousands of children, the majority, the sons and daughters of farmers, the minority belonging to town families, in mountain and foot-hill and plain, making the daily journey to these humble buildings of immense political significance. It leads one further to reflect upon this relationship of Czech and Slovak and Magyar in terms of environment.

First, there come to mind the three clearly-marked regions of Czechoslovakia, the sub-divisions being both of language and of physical feature. To the west lie the two Czech settlement areas of Bohemia and Moravia–Silesia of mainly Hercynian landscape; to the east are the elongated territories of Slovakia and Sub-Carpathian Russia. In the Carpathian lands, Slovakia is distinctive, not only in the culture of its inhabitants, but also in physical framework. It contains the three great concentric zones of highland country, the Beskid [2] or *flysch* belt to the north, the mass of the central Tatra ranges formed of crystalline and volcanic rock, and the inner and piedmont zone of much-eroded volcanic upland. In

[1] The vineyard farmers of the Carpathian piedmont are largely German in origin. The island formed by the branching of the Danube between Bratislava and Komárno, and known as Velký Ostrov Žitný, was dyked and drained by German peasants in the fourteenth century, but this immigrant population has naturally been deeply affected by both Slav and Magyar influences in the course of hundreds of years.

[2] The Beskid arc is mainly in Poland, as well as the northern slopes of the Tatra mass, but the extreme western Beskid ranges, known as the Little Carpathians and White Carpathians belong to the Czechoslovaks and form the borderland between Moravia and Slovakia.

Sub-Carpathian Russia, farther east, the first and third arcs of highland alone are present: the high rugged country of the mighty Tatra, the citadel of Slovak settlement, comes to an end.

Fringing the Slovak Carpathians in the south is the narrow strip of loess and alluvial plain, the monotony of which is broken by the occasional residual stumps of volcanic rock. Across it wind the slow, lower courses of the Carpathian rivers; the line of the waterway being marked by a narrow ribbon of oak and willow trees. This lowland is divided into an eastern and western part. Between the ancient fort of Děvín, perched on its high rock at the confluence of the Morava with the Danube, and Višegrad, just below the junction of the Ipola with the great mainstream, the Slovak–Magyar frontier borders the Little Alföld. The broken foot-hill country of northern Hungary separates this plain from the eastern Slovak lowland, drained by the Hernad tributary of the Tisa. In the Little Alföld, the southern frontier of Slovakia is the Danube, so that the final edging to the Slovak homeland is that of a mighty international waterway with a mature and still growing economy of river transport. This northern rim of the Middle Danube Plains, riverine, lowland, and piedmont, is the region most hotly contested between Slav and Magyar.

In the ninth century, the Magyar tribes invading the Middle Danube basin gradually pressed the Slovak tillers of the plains back into the highlands. In the later Middle Ages, the exploitation of valuable mineral wealth in the Slovak Ore Mountains brought not only the German mining immigrants to the upper Hernad valley in Central Slovakia, but also the accompanying appreciation of the forest resources for strutting and fuel. The Slovak peasants, from the ninth century onwards a subject people, were forbidden to clear wooded land extensively for cultivation and pasture because of the value of the forests to mining enterprise. Hence with the over-population which seems to be part of the inevitable cycle of mountain economies, the Slovak farmers shifted back to the lowlands whenever an opportunity occurred.

In the sixteenth century the Magyar population was again pressed northwards by the Turkish invasion, and the resources of western Slovakia, which had escaped the Ottoman conquest were naturally prized by the surviving Magyar aristocracy. Once more the lowland dwellers shifted up the wide valleys which break up the inner and lower Carpathian ranges. A new awareness of the economic possibilities of the Middle Danube basin in the nineteenth century also brought about a second phase of lively interest in the iron of the Slovak Ore Mountains. Again, Slovak farming was restricted, because the forests were the preserves of the great estate owner and the mining entrepreneur. From a detached point of view, there is much to be said in favour of the rigid protection of mountain forest land against peasant farming; but in the overcrowded Slovak mountain villages a renewal of emigration became imperative, in some cases to the New World and especially to the United States, in others to the plains for seasonal labour, in others again to the mines and factories of Hungary, and finally, when possible, to the northern rim of the Middle Danube lowlands for settlement. When and where Slovak lowland settlement was accomplished, the demographic contrast between the Slovaks and Magyars was startling: the Slovak birth rate was and is so high, the Magyar, in all classes so low.

This traditional struggle for the farm lands of the piedmont and lowland area linking the Danube plains with the northern Carpathians, has affected millions where cultural relations affected only thousands, always excepting the question of the elementary schools. Indeed, by force of circumstances, the Slovak intellectual element over centuries has been relatively small and weak,

even though the great Slav scholars, Kollár, Šafařík, and Štúr were of Slovak origin. The incessant effort on either side to control this zone rich in farming, mining, and transport possibilities has been made pre-eminently by a mass of inarticulate peasants whose whole existence has been coloured by the insecurity and bitterness of a disputed frontier. H. G. S.

THE NATIONAL AIR PHOTOGRAPHIC LIBRARY OF CANADA

An account of this important collection of Air Photographs of the Dominion of Canada was published in the *Journal* for May–June 1942. The Society has now received, by the courtesy of the Department of National Defence for Air of Canada, through the Deputy Minister of Mines and Resources, a fine selection of forty prints from their Library, which are now shown in the Museum. These prints illustrate the main use of the Library, that "the forester, the geologist, the prospector, or the engineer, can study his terrain before going into the field." There are many photographs showing the extent of hard and soft woods, burnt over areas, and the result of logging by strip and high lead methods; there are geological photographs, such as obliques of faults and differentiation of strata; and others of the effects of stripping in mining and water-power sites. There are also a few photographs of town plans and orchards, and several of physiographical features, for example, drainage patterns and drumlins.

We hope to publish a detailed description of some of these photographs together with reproductions in a coming number of the *Journal*.

MEETINGS: SESSION 1943–44

Seventeenth Meeting, 8 May 1944. The President in the Chair

Elections: Mrs. Helen Bennett; Lieut. C. D. Dutton, R.E.; Frederick Ernest Evans; Charles Howard Frobisher, A.M.INST.C.E., A.M.INST.STRUCT.E.; Lieut. William Henry Johns, R.E.; Rev. Horace Edwin Jones, M.A., O.C.F.; Miss Renate Knoepfmacher; Brigadier Cyril Lloyd; Mrs. Ida McComish; Lieut. John Burton Morpeth, R.N.R.; Lieut.-Comdr. Robert Moss, R.N.; Jitenda Nath Mukherjee, M.A.; William Charles Pain; Captain Kenneth Renault, R.E.; Squadron-Leader Godfrey Minchin Digby Roberts, R.A.F.; Desmond Sherry; Captain Edward Dacre Stroud, R.M.; Miss Joan Maureen Sylvester, B.A.; John William Watts; Achill Wheatley; Captain the Rev. C. R. Williams, J.P.

Paper: Valleys of the Hindu Kush. By Mr. K. de B. Codrington

Eighteenth Meeting, 15 May 1944. The President in the Chair

Paper: The formation of ice in lakes and rivers. By Dr. Olaf Devik